IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application of: John W. Evans	)	Examiner:	N. OGDEN
Serial No.: 10/629,642	)	Confirmation No.:	6851
Filing Date: 07/29/2003	)	Group Art Unit:	1751
For: Non-Aqueous Heat Transfer Fluid and Use Thereof	)	Docket No.:	97541.00022

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APPELLANT'S APPEAL BRIEF

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In accordance with the provisions of 35 U.S.C. § 134 and 37 C.F.R. § 41.37, this Appeal Brief is submitted in support of the appeal from the Office Action dated June 4, 2007, finally rejecting claims 1-16, 26-32 and 45-48.

I. REAL PARTY IN INTEREST

The real party in interest in this matter is the assignee of the present application, Evans Cooling Systems, Inc.

II. RELATED APPEALS AND INTERFERENCES

None.

III. STATUS OF THE CLAIMS

Claims 1-16, 18-42 and 45-48 are pending in the application.

Claims 17, 43 and 44 were cancelled during prosecution.

Claims 18-25 and 33-42 were withdrawn from consideration in response to a restriction requirement.

Claims 1-16, 26-32 and 45-48 stand rejected and are on appeal.

IV. STATUS OF AMENDMENTS

None.

V. SUMMARY OF CLAIMED SUBJECT MATTER

As described in the specification and recited in the claims on appeal, the present invention is directed to a non-aqueous, propylene glycol based heat transfer fluid. The heat

transfer fluid contains only additives that are soluble in propylene glycol and ethylene glycol. The non-aqueous heat transfer fluid does not contain any additives, such as silicates or buffers, that require the addition of water to the non-aqueous heat transfer fluid to dissolve the additive or to permit the additive to function in the fluid (e.g. such as by dissociation). The term "non-aqueous" as used in the claims on appeal is defined in paragraph 0056 of the specification as meaning that "water is present as an impurity in the coolant formulation in no greater than a concentration of about 0.5% by weight." The non-aqueous heat transfer fluid contains no added water. As recited in claim 45, and described in the specification at paragraph 0047, the non-aqueous heat transfer fluid may contain a mixture of propylene glycol and ethylene glycol that is up to 60% by weight ethylene glycol. Among the advantages of the non-aqueous heat transfer fluid of the present invention is that a single formulation can be used in many different environments. The non-aqueous heat transfer fluid is a stable solution with its inhibitors and there is no drop-out or gelling of additives, regardless of use or storage.

As further set forth in the Declarations of John Evans dated on April 15, 2005 (Evidence Appendix Ex. 1) and March 5, 2007 (Evidence Appendix Ex. 2), the non-aqueous heat transfer fluids recited in the claims are fundamentally different from prior art aqueous heat transfer fluids. The primary heat transfer medium of an aqueous heat transfer fluid is water. The freezing point depressant for a glycol-based aqueous heat transfer fluid is a glycol, typically ethylene glycol. The glycol and water combination has a boiling point that is dominated by the water; e.g. the boiling point of an unpressurized heat transfer fluid that is 50% water and 50% ethylene glycol is raised just 13° F (7° C) from that of water alone. Water is corrosive toward many cooling system metals and corrosion inhibitors that can dissolve in water are required in order to protect against corrosion.

Essential inhibitors for protection against corrosion by an aqueous glycol-based heat transfer fluid require that water be present in order to keep the inhibitors in solution. The literature is replete with warnings against using a heat transfer fluid that is too concentrated (i.e., with insufficient water) because of the problem of additive drop-out, such as the drop-out of silicates or phosphates. Water is also required in *concentrates* for making aqueous heat transfer fluids. An antifreeze concentrate must contain enough water to keep its additives dissolved during storage prior to the adding of water to make the actual heat transfer fluid.

Use of an antifreeze concentrate that is intended for making an aqueous glycol-based heat transfer fluid as a heat transfer fluid itself (without the additional water) will not work because the inhibitors that require water for solubility will not remain in solution. In an automobile cooling system, for example, the products of additive drop-out are in the form of a gel that will plug heat exchanger passageways and cause the cooling system to malfunction. See Penray Company information sheet (Evidence Appendix Ex. 5).

The non-aqueous heat transfer fluid of the present invention operates in a fundamentally different way than prior art aqueous heat transfer fluids. As recited in claims 1-16 and 26-32, in one embodiment of the invention, the heat transfer medium of the non-aqueous heat transfer fluid of the present invention is propylene glycol. As recited in claims 45-48, in another embodiment of the invention, the heat transfer medium comprises propylene glycol and ethylene glycol (with propylene glycol comprising at least 40% of the glycol component even in embodiments of the invention in which a mixture of ethylene glycol and propylene glycol is used). The parameters regarding the heat transfer depend upon the characteristics of the propylene glycol (or the mixture of glycols if there is more than one). The freezing point of the non-aqueous heat transfer fluid is determined by the freezing point of propylene glycol (or by the

freezing point of the mixture of glycols if there is more than one). The boiling point of the non-aqueous heat transfer fluid is determined by the boiling point of propylene glycol (or by the boiling point of the mixture of glycols if there is more than one).

Water is not added to the non-aqueous heat transfer fluid. The best performance is achieved when the water content is zero. If there is any water present in the heat transfer fluid, it is present only in a small amount as an impurity, not as a heat transfer component, and in any event it is removed from the heat transfer fluid in use. Cooling systems that use a non-aqueous heat transfer fluid of the type described in the claims on appeal benefit from the high boiling points of propylene glycol (369° F, 187° C) and ethylene glycol (387° F, 197° C). These cooling systems can operate without failure at higher temperatures than aqueous systems. The cooling systems do not require pressurization nor do they have any other operating limitations that are based upon the boiling point of water. Any small amount of water vapor that may be present due to water that is present as an impurity is allowed to vent from the system because water is not the coolant. Water-based cooling systems, on the other hand, require pressurization to retain the water within the cooling system because water *is* the coolant. Furthermore, water-based cooling systems fail catastrophically when the coolant exceeds the boiling point of water for the pressure of the system.

Prior to the present invention, the predominant heat transfer fluids were water-based and the prior art was centered on the problems of water-based heat transfer fluids. In the few prior art descriptions of glycol-based, non-aqueous heat transfer fluids, there was either no discussion of the additives required for use or additives were proposed that included additives required for the control of pH. These views resulted in various approaches to the use of glycol-based, non-aqueous heat transfer fluids prior to the disclosure of the present invention that resulted in either

the omission of important additive ingredients or the inclusion of inappropriate additive ingredients that require water to be present in the heat transfer fluids. For example, as discussed in more detail below, some tests of propylene glycol based heat transfer fluids were performed without any corrosion additives present in the fluid, such as those described in Coughenour and Dingley. In other cases, as described for example in Reny, concern about pH caused the inclusion of pH control additives, such as phosphoric acid buffers. In still other cases, as described for example in Mascioli, Greaney and Wood (in antifreeze concentrates that have been incorrectly treated by the Examiner as non-aqueous heat transfer fluids), the heat transfer fluids include water soluble (but non-glycol soluble) additives, such as silicates, that require the presence of added water to dissolve the additives so as to enable them to perform their function. In contrast, the applicant recognized that when the water content is very low, the pH of the fluid is immaterial, and that the heat transfer fluid must avoid all additives that cannot function without water.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Claims 7, 16 and 32 stand rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement. Claims 1-5, 8-12, 14, 26, 28-30, 45-46 and 48 stand rejected under 35 U.S.C. § 102(b) as being anticipated by Reny, WO89/09806. Claims 1-16, 26-32 and 45-48 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Coughenour, Chemical Abstracts 120:195478 or Dingley, Chemicals Abstracts 116:86516 or Evans, U.S. Patent No. 5,031,579 each in view of Mascioli, U.S. Patent No. 5,240,631, or Greaney, U.S. Patent No. 5,422,026. Claims 1-5, 8-11, 13-14, 26-27, 29-32, 45 and 47-48 stand

rejected under 35 U.S.C. § 103(a) as being unpatentable over Wood, U.S. Patent No. 4,455,248. For the reasons set forth below, the rejections are improper and should be reversed.[1]

Applicant notes that on page 3, paragraph 5 of the Office Action, the Examiner states that the application names joint inventors. This is incorrect, and may have been an impression resulting from typographical errors in the caption or other papers filed by the applicant. In any event, John W. Evans is the sole inventor for this application.

VII. ARGUMENT

Rejection Under 35 U.S.C. § 112, First Paragraph

Claims 7, 16 and 32 stand rejected under 35 U.S.C. § 112, first paragraph as failing to comply with the written description requirement. The Examiner states that he cannot find support in the specification for a propylene glycol amount in the fluid of greater than about 98.5% by weight, although the Examiner states that there is support for greater than about 99.0% by weight. The Examiner cites Purdue Pharma L.P. v. Faulding Inc., 230 F.3d 1320, 1328 (Fed. Cir. 2000) to support a rejection because "the specification does not disclose to the skilled artisan that applicant considered this specific data point as part of the invention."

The limitations of claims 7, 16 and 32 are plainly within ranges for the components that are clearly described in the specification. The specification at paragraphs 0050-0051 states that the heat transfer fluid preferably contains propylene glycol and the additives sodium nitrate, tolyltriazole and sodium molybdate, and that "[t]he additives can be present in a range of about 0.05% by weight to about 5.0% by weight, and more preferably not above about 3.0% by

[1] Applicant notes that the corresponding foreign filed applications for the invention described in the present application have been granted. For example, in China, a patent on the invention claimed in this application has been granted in China and was recently enforced there with the help of the U.S. Commercial Service. See "U.S. agency helps coolant company fight fakes in China", Automotive News, October 1, 2007 (Evidence Appendix, Ex. 7).

weight." A skilled artisan would readily recognize that the propylene glycol content of a fluid having these additives within the ranges described is necessarily between 99.85% by weight to about 85.0% by weight. Each of the limitations of claims 7, 16 and 32 are within the ranges described in the specification. Claims 7, 16 and 32 merely recite a specific embodiment of the invention described in the claims.

The Examiner's requirement that the specification exactly and literally describe a particular point within the range in order to claim that embodiment is contrary to the law. The written description requirement of 35 U.S.C. § 112, first paragraph "ensures that, as of the filing date, the inventor conveyed with reasonable clarity to those of skill in the art that he was in possession of the subject matter of the claims." Union Oil of California v. Atlantic Richfield Co., 208 F.3d 989, 997 (Fed. Cir. 2000). "In order to satisfy the written description requirement, the disclosure originally filed does not have to provide in haec verba support for the claimed subject matter at issue." Crown Operations Intern., Ltd. v. Solutia Inc., 289 F.3d 1367, 1376 (Fed. Cir. 2002). See also In re Hayes Microcomputer Prods., Inc., 982 F.2d 1527, 1533 ("[The applicant] does not have to describe exactly the subject matter claimed.").

In Vas-Cath Inc. v. Mahurkhar, 935 F.2d 1555, 1563-64 (Fed. Cir. 1991), the Court stated that "ranges found in applicant's claim need not correspond exactly to those disclosed in [the specification]; the issue is whether one skilled in the art could derive the claimed ranges from the disclosure." In this case, the recited limitations are ***within ranges actually disclosed in the specification.*** Plainly, one skilled in the art could reasonably discern the limitation on propylene glycol in claims 7, 16 and 32 from the description in the specification, and the inventor was in possession of the invention recited in these claims at the time that the original disclosure was

filed. Accordingly, for at least this reason, the rejection of claims 7, 16 and 32 under 35 U.S.C. § 112, first paragraph is improper and should be reversed.

Rejection Under 35 U.S.C. §102(b) Based Upon Reny

Claims 1-5, 8-12, 14, 26, 28-30, 45-46 and 48 stand rejected under 35 U.S.C. §102(b) as anticipated by Reny, WO89/09806. As described in the Declaration of Evans dated April 15, 2005 at ¶¶ 10-12 (Evidence Appendix, Ex. 1) and discussed in detail below, Reny does not describe any composition that meets all of the limitations of the claims on appeal. Specifically, Reny does not teach or describe a non-aqueous heat transfer fluid comprising neat propylene glycol, or combinations of propylene glycol and up to 60% by weight ethylene glycol, that contains less than 0.5% by weight water, and that contains no additives requiring the presence of water to dissolve the additive or to enable the additive to perform its intended function. To the contrary, all of the heat transfer fluids described by Reny that contain propylene glycol and additives contain phosphoric acid and at least 1% by weight water.

Reny describes heat transfer fluids that may contain alkylene glycols, corrosion inhibitor additives, phosphoric acid to buffer the pH of the fluid and up to 10 percent water. The Examiner relies on statements at page 3, lines 1-11 of Reny which generally describe a coolant composition that contains at least 90 weight percent of an alkylene glycol or a mixture of two or more alkylene glycols, a corrosion inhibiting amount of an inhibitor, and from 0 to 3 percent phosphoric acid. This portion of Reny does not describe the use of any particular alkylene glycols, much less describe the use of propylene glycol or combinations of propylene glycol and ethylene glycol as the heat transfer fluid. Moreover, this portion of Reny does not discuss at all whether water is added to a propylene glycol heat transfer fluid.

At page 3, lines 6-7, Reny states that the heat transfer fluids contain "from 0 to 3 weight parts of phosphoric acid." As described in the specification of the present application at, for example, paragraphs 0024 to 0026, phosphoric acid is used in many heat transfer fluids to buffer the pH of the fluid, and these heat transfer fluids require added water to dissolve the phosphoric acid and enable it to function as a buffer. This is consistent with the discussion in Reny at page 5, lines 22-26, where Reny states that phosphoric acid "is employed to maintain the pH of the coolant composition in the range from 7 to 9." Any heat transfer fluid that includes a phosphoric acid buffer necessarily includes added water.

While Reny states at page 5, lines 28-34, that the coolant preferably contains essentially no water, Reny does not specifically mention propylene glycol in connection with this preference. In the immediately preceding paragraph, Reny states, at page 5, lines 21-26, that phosphoric acid is added if necessary to maintain the pH of the coolant between 7 to 9. Although Reny states that "[s]ome alkylene glycol mixtures are within the pH limits, and in such cases no pH adjustment is needed", Reny does not disclose any specific alkylene glycol mixtures that would not require the addition of phosphoric acid as a pH buffer, and he certainly does not describe any propylene glycol coolants, or combinations of ethylene glycol and propylene glycol, that do not require a phosphoric acid buffer and added water. To the contrary, all of the examples of the fluid and preferred embodiments disclosed in Reny, including the examples of additive-containing non-aqueous propylene glycol fluids and mixtures of ethylene glycol and propylene glycol described in the specification and in Table 1, contain at least 1 percent water added to the alkylene glycol, and the addition of phosphoric acid, a substance that requires water to enable it to function. Thus, in all of the heat transfer fluids comprising propylene glycol, or combinations of ethylene glycol and propylene glycol, described by Reny, phosphoric acid and

water are included to form a pH buffer. For phosphoric acid to function in a manner as to affect pH, water must be included in order for the phosphoric acid to ionize. Reny states at page 5, lines 21-23, that phosphoric acid is employed "only if necessary" to maintain pH limits. Reny's examples therefore teach that when the alkylene glycol is either propylene glycol or a mixture of propylene glycol and ethylene glycol, that phosphoric acid and added water are required.

Phosphoric acid, the use of which is taught by Reny in heat transfer fluids comprising ethylene glycol and propylene glycol, is an undesirable ingredient in the claimed non-aqueous heat transfer fluid for a number of reasons. In order for the phosphoric acid to perform its function as an acid, there must be sufficient water added for the phosphoric acid to ionize. Ionized phosphoric acid forms phosphate compounds with engine metals such as iron. The resulting phosphate compounds have limited solubility and will precipitate in a low water environment, such as in a non-aqueous heat transfer fluid. See Declaration of Evans dated April 15, 2005 at ¶ 11 (Evidence Appendix, Ex. 1). For example, a manufacturer of heat transfer fluid additives, Penray Companies, Inc., states that "Silicate and phosphate, while valuable as corrosion inhibitors in engine coolant, have limited solubility. That meant that if the antifreeze . . . got too concentrated in the coolant [i.e. there is not sufficient water, as in a non-aqueous heat transfer fluid], then the excess phosphate and/or silicate would drop out of the coolant." *See* http://www.penray.com/managex/index.asp?x=322&y=323&articlesource=323.

The set of alkylene glycols is very large and is comprised of ethylene glycol, diethylene glycol, triethylene glycol, tetraethylene glycol, propylene glycol, dipropylene glycol, hexylene glycol, 2 ethyl-1,3-hexanediol, 1,5-pentanediol, *and many others*. (Reny adds glycerol to the list by defining it as an alkylene glycol, while it is actually a triol, not a glycol.) There may be alkylene glycols or mixtures of them for which phosphoric acid would not be necessary,

although none of these are specifically identified by Reny. Indeed, on p. 5 lines 24-26, Reny says that "Some alkylene glycol mixtures are within the pH limits, and in such cases no pH adjustment is required." However, Reny teaches that, for propylene glycol and for mixtures containing propylene glycol and ethylene glycol, the addition of phosphoric acid is necessary for pH control.

To anticipate a claim under Section 102(b), a single prior art reference must disclose each and every element set forth in the claim. Apple Computer, Inc. v. Articulate Systems, Inc., 234 F.3d 14 (Fed. Cir. 2000); Verdegaal Bros. v. Union Oil Co. of California, 814 F.2d 628, 631 (Fed. Cir. 1987); MPEP § 2131. Reny's general statement that some undisclosed combinations of alkylene glycols might not require buffering, or that some undisclosed combinations of alkylene glycols might not require added water, is insufficient to anticipate the claims on appeal. As discussed above, all of the heat transfer fluids described by Reny that contain propylene glycol contain a phosphoric acid buffer and added water. Because Reny does not describe a heat transfer fluid comprising propylene glycol, or propylene glycol and ethylene glycol, that contains less than 0.5% by weight water and no additives requiring added water to dissolve or function, Reny does not anticipate claims 1-5, 8-12, 14, 26, 28-30, 45-46 and 48.

At page 4 of the Office Action, the Examiner states his conclusion that Reny is anticipatory, and then directly contradicts his own conclusion by stating that "Reny et al, however, do not specifically teach with sufficient specificity coolant compositions comprising less than 0.5% by weight of water." This is an acknowledgement by the Examiner that Reny does not anticipate the appealed claims. The Examiner goes on to state that "it would have been obvious to one of ordinary skill in the art to decrease the amount of water present in example 1 of Reny". Obviousness is not a proper basis for a rejection under 35 U.S.C. § 102(b). Titanium

Metals Corp. v. Banner, 778 F.2d 775 (Fed. Cir. 1985)(anticipation under Section 102 can be found only if a reference shows exactly what is claimed; where there are differences between the reference disclosures and the claim, a rejection must be based on obviousness under Section 103).

Even if the rejection were considered an obviousness rejection, the Examiner is incorrect that one skilled in the art would have been motivated to reduce the amount of water in example 1 of Reny. Reny teaches that water can be left out of heat transfer fluids containing one or more unspecified alkylene glycols *provided the pH is in the appropriate range*. Reny also teaches that a phosphoric acid buffer is used to control pH only in those cases where it is necessary. In every example provided by Reny that involves propylene glycol and ethylene glycol, a phosphoric acid buffer is used.

The Examiner refers to p. 5, lines 25-45. As there are only 35 lines on page 5, it is assumed the Examiner meant lines 25-35. In this passage, preparation of the coolant begins with the addition of water to the "alkylene glycol." Reny says that "more preferably about 3 percent of water is dissolved in propylene glycol". Then he uses the general "alkylene glycol" as being most preferably used with less than about 1 weight percent water. Some alkylene glycols, according to Reny, do not require buffers but Reny teaches that, for propylene glycol and for mixtures containing propylene glycol and ethylene glycol, the addition of phosphoric acid is necessary for pH control.

The Examiner's assertion on page 7 of the Office Action that Reny's page 9 teaches propylene glycol and propylene glycol/ethylene glycol compositions that contain little or no water is defective because the only compositions shown with less than 1% water are pure propylene glycol without additives (designated as C_1) and a mixture of propylene glycol and

ethylene glycol without additives (designated as C_2). Both C_1 and C_2 have asterisks that indicate that neither is "an example of the invention". These compositions were provided for comparison only, and the results show that they are not practical as heat transfer fluids because they are highly corrosive.

On page 10 of the Office Action, the Examiner asserts that Reny's examples 1, 2, C_1 and C_2 "specifically teach compositions containing no phosphoric acid and no added water." As explained above, examples C_1 and C_2 have no additives at all, are not practical heat transfer fluids, and are present for comparative purposes only. Example 1 is a fluid containing only propylene glycol as a heat transfer medium and example 2 is a fluid containing both propylene glycol and ethylene glycol as a heat transfer medium. The fluids of examples 1 and 2 of Reny each contain 1 percent by weight water and phosphoric acid.

Reny does not teach or suggest embodiments of a heat transfer fluid comprising propylene glycol or ethylene glycol/propylene glycol mixtures which contain no additives that require water in the heat transfer fluid to dissolve the additive or to enable the additive to function as recited by the instant claims. Although Reny describes in a general way unspecified alkylene glycols that may not require buffers (and hence water), none of Reny's embodiments that use propylene glycol as the only glycol, or that use mixtures of propylene glycol and ethylene glycol, are in that category. Reny teaches that, for propylene glycol and for mixtures containing propylene glycol and ethylene glycol, the addition of phosphoric acid is necessary for pH control. Phosphoric acid requires the presence of water in order for it to ionize so that it can perform its function to control pH.

A prior art reference must be considered in its entirety, including portions that lead away from the claimed invention. MPEP § 2141.03; W.L. Gore & Associates, Inc. v. Garlock, Inc., 721 F.2d 1540 (Fed. Cir. 1983), cert. denied, 469 U.S. 851 (1984).

> It is impermissible within the framework of section 103 to pick and choose from any one reference only so much of it as will support a given position to the exclusion of other parts necessary to the full appreciation of what such reference fairly suggests to one skilled in the art.

In re Wesslau, 353 F.2d 238, 241 (CCPA 1965). The Federal Circuit has held that it is improper to consider a single line taken out of context from a reference without considering other statements in the reference that argue against obviousness. Bausch & Lomb, Inc. v. Barnes-Hind/Hydrocurve, Inc., 796 F.2d 443, 448 (Fed. Cir. 1986).

Reny at most teaches that some undisclosed combinations of alkylene glycols may not require addition of phosphoric acid and water, and that these components are only added when necessary. In all of the fluids described in Reny that contain propylene glycol, however, Reny describes the addition of phosphoric acid and at least 1% water. Although styled by Reny as a "non-aqueous" composition, Reny's requirement of phosphoric acid in propylene glycol and propylene glycol/ethylene glycol mixtures necessitates a minimum amount of water. The action of the phosphoric acid creates phosphates that further require water for the phosphates to be in solution. Below a minimum amount of water, the phosphates will not remain in solution and will drop out as solids that can plug heat exchanger passages. See Declaration of John Evans dated March 5, 2007 at ¶ 11 (Evidence Appendix, Ex. 2). Reny does not teach, suggest or otherwise describe a heat transfer fluid containing propylene glycol having less than 0.5% water, nor does Reny suggest the desirability of such a fluid. Therefore, when Reny is considered in its entirety,

as required under an obviousness rejection, Reny teaches that propylene glycol based heat transfer fluids require the addition of phosphoric acid and water.

Accordingly, Reny does not teach, describe or otherwise suggest a non-aqueous heat transfer fluid as defined in the specification and recited in the claims on appeal comprising propylene glycol with less than 0.5% by weight water and that does not contain any additives that require water to dissolve the additives in the fluid or to enable the additives to function in the fluid. For at least these reasons, claims 1-5, 8-12, 14, 26, 28-30, 45-46 and 48 are not anticipated by Reny, nor are the fluids recited by these claims obvious in view of Reny.

Rejection Under 35 U.S.C. §103(a) Based Upon Coughenour, Dingley or Evans

Claims 1-16, 26-32 and 45-48 stand rejected under 35 U.S.C. § 103 based upon Coughenour, Dingley or Evans in view of each of Mascioli and Greaney. As set forth in detail below, none of these references can be properly combined in a manner which results in the non-aqueous heat transfer fluid of the claims on appeal.

Coughenour describes engine tests which were conducted using non-aqueous propylene glycol as an engine coolant. The tests performed by Coughenour included a 500 hour durability test. Coughenour states that the results of the tests quantified "some of the presumed advantages and disadvantages" of the use of non-aqueous propylene glycol, and that the results formed the basis for further work "using total-vehicle systems." Coughenour's SAE Paper 930584, *Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines*, from which the abstract cited by the Examiner was taken, states in its *summary and conclusions* (last page), "Non-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression." See Evidence Appendix, Ex. 6. This statement suggests that there is no need for any coolant additives and

nowhere in the Coughenour paper is there any mention of coolant additives or any need for coolant additives. Coughenour does not describe, teach or suggest a non-aqueous propylene glycol heat transfer fluid having dissolved inhibitors as recited in the claims on appeal, nor does Coughenour suggest the desirability of adding corrosion inhibitors to the heat transfer fluid.

Dingley describes the use of monopropylene glycol both as a component of an engine coolant and as the entire coolant. Dingley describes the use of monopropylene glycol alone in general terms, and Dingley does not teach or suggest a non-aqueous propylene glycol heat transfer fluid having dissolved inhibitors as recited in the claims on appeal. Dingley's paper, *Aqueous and Non-Aqueous Engine Coolants Based on Propylene Glycol*, from which the abstract cited by the Examiner was taken, states that "in a commercial antifreeze concentrate [i.e. a coolant concentrate for *aqueous* applications], there can be up to ten other ingredients which act to prevent corrosion of the metals of the engine and reduce the degradation of the glycol." p. 146, lines 6-8. See Evidence Appendix, Ex. 4. With regard to *non-aqueous* applications (see section 6, beginning on page 149), Dingley is silent regarding coolant additives or any need for coolant additives. Dingley does not describe, teach or suggest a non-aqueous propylene glycol heat transfer fluid having dissolved inhibitors as recited in the claims on appeal, nor does Dingley suggest the desirability of adding corrosion inhibitors to the non-aqueous heat transfer fluid. Furthermore, Dingley is silent regarding criteria for determining what additives might be inappropriate for a non-aqueous heat transfer fluid.

Evans describes a cooling system for internal combustion engineers for use with a substantially anhydrous, boilable liquid coolant having a saturation temperature higher than that of water. Evans describes tests of the cooling system that were conducted using neat propylene glycol as the coolant in the improved design. As discussed in the Declaration of Evans dated

April 15, 2005 at ¶¶ 6-9 (Evidence Appendix, Ex. 1), Evans does not describe, teach or suggest a non-aqueous heat transfer fluid containing corrosion inhibitors of the type recited in the claims, nor does Evans suggest the desirability of adding corrosion inhibitors to the fluid.

Thus, as recognized by the Examiner, each of Coughenour, Dingley and Evans do not describe, teach or suggest a non-aqueous propylene glycol based heat transfer fluid having corrosion inhibitors which are soluble in propylene glycol and which contain no additives that require water in the heat transfer fluid to dissolve the additive or enable the additive to function as recited in the claims on appeal. The Examiner attempts to address this deficiency in these references by stating that each of them can be combined with either Mascioli or Greaney to arrive at the claimed compositions. However, Mascioli and Greaney each require additives for their respective heat transfer fluids that require water in the heat transfer fluid to dissolve the additives to permit the additives to function. The addition of water is consistent with the prevailing view of those skilled in the art at the time of the invention, as set forth in detail in the Declaration of John Evans dated March 5, 2007 at ¶¶ 3-5 (Evidence Appendix, Ex. 2), that concentrates for making aqueous heat transfer fluids had to contain enough water in the concentrate to keep the additives dissolved during storage, prior to the addition of water to formulate the heat transfer fluid to be used in the cooling system.

Mascioli describes corrosion-inhibited antifreeze concentrate formulations and aqueous corrosion-inhibited antifreeze formulations for use in engines. Mascioli states that antifreeze formulations in which propylene glycol is the primary component formed undesirable oxidation products. Col. 2, lines 19-24. Mascioli solves this problem by adding phosphorous acid to the formulation, as well as an alkali metal hydroxide to provide a final pH of 7-10 for the concentrate plus water coolant formulation. Col. 2, lines 24-27, 49-51. As described at col. 2,

lines 42-43 and col. 3, lines 3-4, Mascioli also includes silicates in the heat transfer fluid in the form of sodium silicate, which is soluble in water, but insoluble in alcohol (See Information sheet from the Occupational Safety & Health Administration at http://www.osha.gov/dts/chemicalsampling/data/CH_267715.html). These additives taught by Mascioli require the presence of water in the concentrate to dissolve or enable the additive to function, and Mascioli states that the concentrate formulation contains 1 to 5% by weight water. Col. 2, lines 47-48, Table 1.

At page 8 of the Office Action, the Examiner states that "it appears that a buffer is not required to be employed" in the composition described by Mascioli. In fact, Mascioli clearly shows in Table 1 that phosphorus acid is added to the formulation as a buffer, as well as sodium silicate. Both of these additives require water.

A rejection under Section 103 cannot be based on selecting only portions of a reference to support the rejection, to the exclusion of other parts of the reference necessary to understanding what the reference fairly suggests to one skilled in the art. In re Wesslau, 353 F.2d 238, 241 (CCPA 1965). When Mascioli is considered as a whole, as is required under section 103, Mascioli includes additives requiring water to remain in solution, as well as 1% to 5% added water. Therefore, combining any one of Coughenour, Dingley or Evans with Mascioli results in a concentrate containing additives requiring water to remain in solution or to perform their function, and between 1% and 5% added water. Accordingly, the combination of these references results in a heat transfer fluid that does not meet all of the limitations of the claims on appeal.

Greaney describes a heat transfer concentrate similar to that described in Mascioli, except that the fluid of Greaney does not contain phosphates. Col. 2, lines 30-32. As with Mascioli, the

heat transfer fluid contains silicates, an alkali metal hydroxide for pH control, and 1% to 5% by weight added water. Col. 2, lines 37-52 and Table 1. Therefore, when read as a whole, Greaney teaches a heat transfer concentrate that necessarily includes additives requiring water to remain in solution or to perform their function, and between 1% and 5% added water. Accordingly, the combination of any one of Coughenour, Dingley or Evans with Greaney results in a heat transfer fluid that does not meet all of the limitations of the claims on appeal.

Thus, each of Mascioli and Greaney teach the addition of an additive requiring water in the heat transfer fluid, and each specifically teaches the addition of some amount of water to the heat transfer fluid. It is only by ignoring these teachings in Mascioli and Greaney that the Examiner is able to construct a composition meeting all of the limitations of the claims on appeal. "Determination of obviousness cannot be based on the hindsight combination of components selectively culled from the prior art to fit the parameters of the patented invention." ATD Corp. v. Lydall, Inc., 159 F.3d 534, 546 (Fed. Cir. 1998). Accordingly, the rejection of claims 1-16, 26-32 and 45-48 under 35 U.S.C. § 103 based upon Coughenour, Dingley or Evans in view of each of Mascioli and Greaney is improper and should be reversed.

Rejection Under 35 U.S.C. §103(a) Based Upon Wood

Claims 1-16, 26-32 and 45-48 stand rejected under 35 U.S.C. § 103(a) based upon Wood. As set forth in detail below, Wood cannot be properly modified in a manner which results in the non-aqueous heat transfer fluid of the claims on appeal. The composition described by Wood "necessarily" contains sodium metasilicate. Col. 3, lines 27-55. Although Wood states that "the antifreeze may be formulated as a concentrate using little or no water", (col. 3, lines 7-8), the requirement that the fluid described by Wood contain sodium metasilicate necessitates the addition of sufficient water for the sodium metasilicate to dissolve and remain in solution, i.e. in

order for the sodium metasilicate to function. As set forth in the information sheet from the Occupational Safety & Health Administration (OSHA), (http://www.osha.gov/dts/chemicalsampling/data/CH_267715.html) (Evidence Appendix, Ex. 3) sodium metasilicate is not soluble in alcohols such as glycols, but is readily soluble in water. Accordingly, for at least this reason, Wood does not teach or suggest a heat transfer fluid composition as recited in the claims, which recite that the heat transfer fluids of the present invention contain no additive requiring the presence of water in the fluid to dissolve the additive or to enable the additive to function.

Despite the applicant's evidence that sodium metasilicate is insoluble in alcohols, the Examiner on page 9 states, "Note, that, while the sodium metasilicate may be soluble in alcohol, Wood clearly suggests embodiments which contain sodium metasilicate and also may contain no water." As is clear from the evidence presented by the applicant, sodium metasilicate is *not* soluble in alcohol, and the Examiner has no basis to "note" that it may be. Moreover, the "suggestion" by Wood is the statement that the concentrate "may contain little or no water." Wood does not provide any example of a heat transfer fluid containing sodium metasilicate without water, and indeed no such fluid can be formed. Wood must be read from the perspective of one skilled in the art. See Velander v. Garner, 348 F.3d 1359 (Fed. Cir. 2003)(the prior art must be viewed from the perspective of a person skilled in the art at the time of the invention). Because the undisputed evidence of record demonstrates that sodium metasilicate is not soluble in alcohol, and those skilled in the art would immediately recognize this physical fact, Wood's statement that the concentrate *may contain no water* is untrue and cannot be relied upon to reject the claims under Section 103.

At page 6 of the Office Action, the Examiner states that Wood teaches that the compositions may contain "little or no water" in concentrates. Even in the description of the concentrates, however, Wood states that the concentrates typically contain added water. As described in the Declaration of John Evans dated March 5, 2007 at ¶ 4 (Evidence Appendix, Ex. 2), even in the concentrate form, it is necessary that the additives remain dissolved. Accordingly, to the extent that Wood suggests a concentrate having sodium metasilicate and no added water, the concentrate is not even operative for its intended purpose of awaiting the addition of water for use as a heat transfer fluid.

Moreover, Wood specifically states that in use, substantial amounts of water must be added to the fluid. This is required to ensure that water soluble additives, such as sodium metasilicate, do not precipitate out of solution in use. As described in the Declaration of John Evans dated March 5, 2007 at ¶¶ 3-5 (Evidence Appendix, Ex. 2), precipitation of water soluble additives during use is a substantial problem with heat transfer fluids which can ruin a heat transfer system. If the concentrate of Wood, which "necessarily" contains sodium metasilicate, were formulated with no water, the sodium metasilicate would not be in a dissolved form, and its direct use as a heat transfer fluid would certainly cause problems in any heat transfer system in which it was used. The sodium metasilicate would drop out and plug the flows passages of the system.

Finally, although Wood generally states that mixtures of glycols may be used in the anti-freeze compositions described therein, Wood does not teach or suggest combining ethylene glycol and propylene glycol in any specific proportions, much less in the proportions recited in the claims on appeal. Wood is therefore insufficient to support a rejection under 35 U.S.C. § 103(a). See In re Baird, 16 F.3d 380, 382 ("The fact that a claimed compound may be

encompassed by a disclosed generic formula does not by itself render that compound obvious."); MPEP § 2144.08.

Accordingly, for at least these reasons, the rejection of claims 1-16, 26-32 and 45-48 stand rejected under 35 U.S.C. § 103(a) based upon Wood should be reversed.

VIII. CONCLUSION

For the foregoing reasons, it is respectfully submitted that reversal of the final rejection of claims 1-16, 26-32 and 45-48 is warranted and such action is earnestly solicited.

A Petition for a One Month Extension of Time and the associated fee has been filed herewith. No additional fee is believed to be required. However, if any additional fee is required, or otherwise if necessary to cover any deficiency in fees already paid, authorization is hereby given to charge any required fees to deposit account no. 50-3569; further, if any additional extension of time is required, please consider this a petition therefor, and authorization is hereby given to charge the associated extension fee to deposit account no. 50-3569.

Respectfully submitted,

Date: December 4, 2007

By: E. E. Grondahl

Eric E. Grondahl
Registration No. 46,741
Attorney for Applicants

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Fax: (860) 724-3397

IX. CLAIMS APPENDIX

1. A heat transfer system comprising a non-aqueous heat transfer fluid,-the heat transfer fluid comprising propylene glycol containing less than about 0.5 weight percent water and about 0.05 to about 5.0 weight percent of at least one propylene glycol soluble additive selected from the group consisting of a molybdate salt, nitrate compound and an azole compound, wherein the heat transfer fluid contains no additive that requires water in the heat transfer fluid to dissolve the additive or enable the additive to function.

2. The heat transfer system of claim 1 wherein the heat transfer fluid includes from about 84.5 to about 99.85 weight percent propylene glycol.

3. The heat transfer system of claim 1 wherein the said molybdate salt is sodium molybdate.

4. The heat transfer system of claim 1 wherein said nitrate compound is sodium nitrate.

5. The heat transfer system of claim 1 wherein said azole compound consists of tolyltriazole.

6. The heat transfer system of claim 1 wherein the said propylene glycol is present in a concentration of about 94.5% to about 99.85% by weight, and the propylene glycol soluble additive comprises a mixture of sodium molybdate, sodium nitrate and tolyltriazole.

7. The heat transfer system of claim 1 wherein said propylene glycol is present in a concentration of about 98.5% by weight, and said propylene glycol soluble additive comprises a mixture of about 0.5% sodium molybdate by weight, about 0.5% sodium nitrate by weight, and about 0.5% tolyltriazole by weight.

8. The heat transfer system of claim 1 wherein the heat transfer system is an internal combustion engine heat exchange system.

9. The heat transfer system of claim 1 wherein the heat transfer system is a motor vehicle engine heat exchange system.

10. A non-aqueous heat transfer fluid composition effective for use in heat exchange systems comprising propylene glycol containing less than about 0.5 weight percent water and about 0.05 to about 5.0 weight percent of at least one propylene glycol soluble additive selected from the group consisting of a molybdate salt, a nitrate compound and an azole compound, wherein the heat transfer fluid contains no additive that requires water in the fluid to dissolve the additive or to enable the additive to function.

11. The heat transfer fluid of claim 10 wherein the heat transfer fluid includes from about 84.5 to about 99.85 weight percent propylene glycol.

12. The heat transfer fluid of claim 10 wherein said molybdate salt is sodium molybdate.

13. The heat transfer fluid of claim 10 wherein said nitrate compound is sodium nitrate.

14. The heat transfer fluid of claim 10 wherein said azole compound consists of tolyltriazole.

15. The heat transfer fluid of claim 10 wherein said propylene glycol is present in a concentration of about 94.5% to about 99.85% by weight, and the propylene glycol soluble additive comprises a mixture of sodium molybdate, sodium nitrate and tolyltriazole.

16. The heat transfer fluid of claim 10 wherein said propylene glycol is present in a concentration of about 98.5% by weight, and said propylene glycol soluble additive comprises a mixture of about 0.5% sodium molybdate by weight, about 0.5% sodium nitrate by weight, and about 0.5% tolyltriazole by weight.

26. A non-aqueous heat transfer fluid composition effective for use in heat exchange systems consisting essentially of a non-buffered propylene glycol and about 0.05 to about 5.0 weight percent of at least one propylene glycol soluble additive selected from the group consisting of a molybdate salt, a nitrate compound and an azole compound, the composition comprising less than about 0.5 weight percent water.

27. The heat transfer fluid composition of claim 26 wherein the heat transfer fluid composition includes from about 84.5 to about 99.85 weight percent non-buffered propylene glycol.

28. The heat transfer composition of claim 26 wherein said molybdate salt is sodium molybdate.

29. The heat transfer composition of claim 26 wherein said nitrate compound is sodium nitrate.

30. The heat transfer composition of claim 26 wherein said azole compound consists of tolyltriazole.

31. The heat transfer composition of claim 26 wherein said propylene glycol is present in a concentration of about 94.5% to about 99.85% by weight, and the propylene glycol soluble additive comprises a mixture of sodium molybdate, sodium nitrate and tolyltriazole.

32. The heat transfer composition of claim 26 wherein said propylene glycol is present in a concentration of about 98.5% by weight, and said propylene glycol soluble additive comprises a mixture of about 0.5% sodium molybdate by weight, about 0.5% sodium nitrate by weight, and about 0.5% tolyltriazole by weight.

45. A non-aqueous heat transfer fluid for use in a heat transfer system comprising:

a. propylene glycol;

b. ethylene glycol in the range of between 0 and 60 weight percent of the total weight of the propylene glycol and the ethylene glycol in the heat transfer fluid; and

c. about 0.05 to about 5.0 weight percent of at least one additive soluble in propylene glycol selected from the group consisting of a molybdate salt, nitrate compound, and an azole compound, wherein the heat transfer fluid contains no additive that requires water in the fluid to dissolve the additive or to enable the additive to function, and wherein the resulting heat transfer fluid contains less than about 0.5 weight percent water.

46. The heat transfer fluid of claim 45, wherein the molybdate salt is sodium molybdate.

47. The heat transfer fluid of claim 45, wherein the nitrate compound is sodium nitrate.

48. The heat transfer fluid of claim 45, wherein the azole compound is tolyltriazole.

X. EVIDENCE APPENDIX

1. Declaration of Evans Pursuant to 37 C.F.R. § 1.132 dated April 15, 2005.

2. Declaration of John Evans Dated March 5, 2007.

3. Information sheet from the Occupational Safety & Health Administration from web site address http://www.osha.gov/dts/chemicalsampling/data/CH_267715.html.

4. Dingley, *Aqueous and Non-Aqueous Engine Coolants Based on Propylene Glycol,* from Chemicals for the Automotive Industry, p. 145-152.

5. Penray Company web site at http://www.penray.com/managex/index.asp?x=322&y=323&articlesource=323

6. Coughenour, *Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines.*

7. Automotive News, October 1, 2007, "U.S. agency helps coolant company fight fakes in China".

EXHIBIT 1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appln No.:	10/629,642	)
Filed:	July 29, 2003	)
Applicant:	John W. EVANS	)
Title:	NON-AQUEOUS HEAT TRANSFER FLUID AND USE THEREOF	)
Art Unit:	1751	)
Examiner:	Ogden Jr., Necholus	)
Attorney Docket No.:	79213	)
Customer No.:	22242	)

OIPE JC135 APR 2 0 2005 PATENT & TRADEMARK OFFICE

Confirmation No. 6851

CERTIFICATE OF MAILING

I hereby certify that this paper is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to the Commissioner for Patents, P.O Box 1450, Alexandria, VA 22313-1450, on this date.

4/17/05 Date

Timothy E. Levstik
Registration No. 30,192
Attorney For Applicant(s)

DECLARATION OF EVANS PURSUANT TO 37 C.F.R. §1.132

Commissioner of Patents
P.O. Box 1450
Alexandria, VA 22313-13

Sir:

Inventor, John W. Evans, pursuant to 37 C.F.R. §1.132, declares as follows:

1. I am the inventor for the above-referenced patent application.

2. I have reviewed an article entitled "Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines", by Coughenour et al., an article entitled "Aqueous and Non-Aqueous Engine Coolants Based On Propylene Glycol" by Dingley, United States Patent No. 5,240,631 to Mascioli et al., and United States Patent No. 5,422,026 to Greaney, and United States Patent No. 5,387,360 to Uekusa et al.

3. The Coughenour and Dingley articles describes the use of 100% propylene glycol as a coolant without addition of propylene glycol soluble additives. The Coughenour article concludes in pertinent part

> "Non-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression. It also provides a greater margin of boil-over and vapor blanketing protection at a lower cooling system operating pressure. Cavitation damage in the coolant pump should be eliminated. Cooling system maintenance and chemical addition should be greatly simplified."

4. Mascioli, Greaney and Uekusa describe the use of molybdate, nitrate or azole compounds in an aqueous coolant.

5. As of the time of the filing of the parent of the instant application in 1993, a person having ordinary skill would have not understood Mascioli, Greaney and Uekusa to suggest adding corrosion inhibition additives, such as molybdates, nitrates or azoles without buffering, to a completely non-aqueous coolant because, as discussed more fully below, those with ordinary skill would have been taught either (a) a fear of water, and hence, buffering and corrosion inhibition additives were needed, or (b) a person of ordinary skill would have thought such additives would not have been necessary in a coolant where there was no water with which to create a corrosion or cavitation problem. What was surprising and unexpected was that such corrosion inhibition additives would have been needed in a neat or non-aqueous coolant system where heat and propylene glycol created an unexpected corrosion problem.

6. I have reviewed U.S. Patent No. 5,031,579, of which I am also an inventor.

7. The '579 patent describes the use of 100% propylene glycol as a coolant. The '579 teaches one of ordinary skill the fear of water in a propylene glycol cooling system. A desiccant material is even used to make sure that the coolant in the system remains moisture free. See column 10, lines 55-68. As of 1993 a person of ordinary skill would have seen the propylene glycol coolant of the

'579 patent, i.e. without any buffering and corrosion inhibiting additives, would only be acceptable for short term usage, since the lack of additives would result in reactions with metals in the system and subsequent and rapid deterioration of the coolant.

8. Because of a fear of water for one of ordinary skill in the art as of 1993, such a person would not have understood the '579 patent to suggest the use of 100% propylene glycol with corrosion inhibition additives and without the use of a buffer to reduce acidity for a commercially viable coolant. Instead, one of ordinary skill in the art would have added a buffer along with corrosion inhibition additives to the 100% propylene glycol of the '579 patent because one of ordinary skill would expect that a buffer would be needed to reduce acidity. One of ordinary skill in the art, based on the '579 patent, ***would not have used a non-buffered propylene glycol composition with corrosion inhibition additives*** because of the belief that high acidity associated with even trace amounts of water in the composition, which normally results from gradual absorption of water during use in an engine, caused an unacceptable risk of corrosion.

9. Moreover, at about the time of the '579 patent and a bit later, Coughenour knowing about the '579 patent concluded that "[N]on-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression" and that "[C]ooling system maintenance and chemical addition should be greatly simplified." This statement and the Coughenour and Dingley articles suggest that 100% propylene glycol would not need corrosion inhibitor additives because they were not needed and a person having ordinary skill would not want to add corrosion inhibitors were they were not needed, "chemical addition should be greatly simplified."

10. I have read PCT/US89/01544 (Reny et al.). The Reny et al. publication does not exemplify coolant compositions which contain less than 0.5 weight percent water. Indeed, Reny's

compositions can have almost 10 weight percent water which would have been feared as corrosive and would have been viewed as needing buffers and corrosive inhibiting additives.

11. At page 2, line 18, Reny et al. describe two of my patents USP Nos. 4,550,694 and 4,630,572 and says these related to systems with little or no water. That is not true, propylene glycol systems were thought to have water in them. Both of these patents describe propylene glycol cooling systems, but because propylene glycol is miscible with water, it was thought such systems were hygroscopic and were assumed to have water present. See column 17, lines 26-33 of the '694 patent which says:

> If the coolant is miscible with water and a small amount of water is in solution with the coolant, most of the coolant vapor will condense within coolant liquid that is lower in temperature than the saturation temperature of the coolant and higher in temperature than the saturation temperature of water, but not all of it. Coolants miscible with water are hygroscopic and should be assumed to contain some water..

In the same paragraph describing my patents (which assumed propylene glycol coolants had water), when Reny said that "uninhibited glycols used as anhydrous coolants are corrosive to a typical cooling system components...", a person of ordinary skill would have understood Reny as seeing such systems as corrosive because they were assumed to have water in them as an undesirable element. See column 13, lines 34-41 of the '694 patent. At least a portion of those skilled in the art (except for those like Coughenour and Dingley) thought "anhydrous propylene glycol systems" had water in them because they were hygroscopic In any event, even if Reny did mean that the propylene glycol systems he was referring to were completely without water, as I have stated below, Reny did not suggest any corrosion inhibitors that would work in systems that had essentially no water.

12. Unexpectedly, and opposed to what would have been expected by one of ordinary skill in the art, the present invention ***does not require the addition of buffer*** or more than about 0.5 weight percent water ***with the addition of propylene glycol soluble corrosion inhibiting additives***. This is because a coolant with less than 0.5 weight percent water with the remainder of propylene glycol unexpectedly dehydrates itself when subjected to engine heat and a low system pressure, and

does not gather corrosive water. Moreover, the use of a molybdate salt, a nitrate compound and/or azole compound in a propylene glycol coolant with less than 0.5 weight percent water would not have necessarily been seen as a corrosion inhibitor in a system with essentially no water. Corrosion in such a system would come from the propylene glycol and not water. It would not have been obvious to a person of ordinary skill that a system with essentially no water would have been corrosive in an engine cooling system, and possibly more important, whether corrosion inhibitors that worked in systems with water or at least some water would work in systems that had essentially no water.

13. If a person of ordinary skill as of 1993 concluded that despite being hygroscopic, a system with 100% propylene glycol did not need additives because as stated by Coughenour "[N]on-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection...", that person would not have added additives because they could be deleterious to a cooling system. For example, (a) if additives were thought to be needed because of water in the propylene glycol coolant and if in reality the understanding was that you did not have water in the system–no additives would have been thought needed; (b) additives react with each other causing problems; (c) additives were known to not stay in solution/suspension without water; and (d) additives tend not to stay in solution/suspension without balancing their relative amounts and agitation. If additives fall out of solution/suspension, merely agitating the coolant would not cure the problem because when they fall from solution/suspension, the additives congeal at low point (regions) in the cooling system.

14. With the non-buffered propylene glycol coolant of the invention, the additives do not fall from solution/suspension without water. The coolant can be stored for years without congealing. Moreover, the additives do not fall from solution/suspension during use because of a lack of water or an imbalance in relative additive amounts where the imbalance has developed over time and use. In a test vehicle, we have run the non-buffered coolant of the invention for about 1,000,000 miles

without significant loss of additives, without the additives falling out of solution/suspension and without significant corrosion of the components which are in contact with the coolant.

The undersigned, being warned that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. §1001) and may jeopardize the validity of the application or any patent issuing thereon, hereby declares that the above statements made of my own knowledge are true and that all statements made on information and belief are believed to be true.

Date: 4/15/05

John W. Evans

John W. Evans

APPENDIX 1 (CLAIMS 1-8)

1. A method of cooling a heat exchange system which comprises circulating a composition in said system, said composition comprising at least about 94.5 weight percent non-buffered propylene glycol, and about 0.05 to about 5.0 weight percent of at least one propylene glycol soluble additive selected from the group consisting of a molybdate salt, a nitrate compound and an azole compound, the composition comprising less than about 0.5 weight percent water.

2. The method of claim 1 wherein said molybdate salt is sodium molybdate.

3. The method of claim 1 wherein said nitrate compound is sodium nitrate.

4. The method of claim 1 wherein said azole compound consists of tolyltriazole.

5. The method of claim 1 wherein said propylene glycol is present in a concentration of about 94.5%to about 99.85% by weight, and the propylene glycol soluble additive comprises a mixture of sodium molybdate, sodium nitrate and tolyltriazole.

6. The method of claim 1 wherein said propylene glycol is present in a concentration of greater than about 99.0% by weight, and said propylene glycol soluble additive comprises a mixture of about 0.3% sodium molybdate by weight, about 0.3% sodium nitrate by weight, and about 0.3% tolytriazole by weight.

7. The method of claim 1 wherein the heat exchange system is an internal combustion engine heat exchange system.

8. The method of claim 1 wherein the heat exchange system is a motor vehicle engine heat exchange system.

EXHIBIT 2

OIPE MAR 07 2007

CERTIFICATE OF MAILING

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service on the date shown below with sufficient postage as First Class Mail in an envelope addressed to Mail Stop: Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Date: March 5, 2007 | Name: Nancy Doble | Signature: Nancy Doble

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of John W. Evans, et al.	)	Examiner:	N. Ogden
Serial No.: 10/629,642	)	Confirmation No.:	6851
Filing Date: July 29, 2003	)	Group Art Unit:	1751
For: NON-AQUEOUS HEAT TRANSFER FLUID AND USE THEREOF	)	Docket No.:	97541.00022

Dated at Hartford, Connecticut this 5th day of March, 2007

Mail Stop: Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION OF JOHN EVANS

I, John Evans, do hereby declare and say as follows:

1. I am an inventor of the above-referenced patent application regarding methods for cooling internal combustion engines or other heat generating devices using an ethylene glycol based aqueous heat transfer fluid. I am also the Chairman of the assignee of the patent application, Evans Cooling Systems, Inc.

2. The non-aqueous heat transfer fluids recited in the claims of the above-referenced patent application are fundamentally different from prior art aqueous heat transfer fluids. The primary heat transfer medium of an aqueous heat transfer fluid is water. The freezing point depressant for a glycol-based aqueous heat transfer fluid is a glycol, typically ethylene glycol. The glycol and water combination also has a boiling point that is slightly higher than water

alone. Water is corrosive toward many cooling system metals and corrosion inhibitors that can dissolve in water are required in order to protect against corrosion.

3. Essential inhibitors for protection against corrosion by an aqueous glycol-based heat transfer fluid require that water be present in order to keep the inhibitors in solution. The literature is replete with warnings against using heat transfer fluid that are too concentrated (i.e., with insufficient water) because of the problem of additive drop-out, such as the drop-out of silicates or phosphates.

4. Water is also required in *concentrates* for making aqueous heat transfer fluids. The concentrate must contain enough water to keep its additives dissolved during storage prior to the adding of water to make the actual heat transfer fluid.

5. Use of an antifreeze concentrate that is intended for making an aqueous glycol-based heat transfer fluid as a heat transfer fluid itself (without the additional water) will not work because the inhibitors that require water for solubility will not remain in solution. In an automobile cooling system, for example, the products of additive drop-out are in the form of a gel that will plug heat exchanger passageways and cause the cooling system to malfunction.

6. The non-aqueous heat transfer fluid of the present invention operates in a fundamentally different way than prior art aqueous heat transfer fluids. The heat transfer medium of the propylene glycol based non-aqueous heat transfer fluid of the present invention is propylene glycol. The parameters regarding the heat transfer depend upon the characteristics of the propylene glycol (or the mixture of glycols if there is more than one). The freezing point of the non-aqueous heat transfer fluid is determined by the freezing point of propylene glycol (or by the freezing point of the mixture of glycols if there is more than one). The boiling point of the

propylene glycol-based non-aqueous heat transfer fluid is determined by the boiling point of propylene glycol (or by the boiling point of the mixture of glycols if there is more than one).

7. Water is not added to the non-aqueous heat transfer fluid . If water is present, it is in small amounts as an impurity. The best performance is achieved when the water content is zero. If there is localized boiling of a non-aqueous glycol-based heat transfer fluid that contains some water present as an impurity, the resulting vapor would be almost entirely water vapor. The water vapor would not condense in the surrounding fluid and would become vented from the system.

8. Prior to the present invention, the most common heat transfer fluids were water-based and the prior art was primarily directed toward water-based heat transfer fluids. In the limited descriptions of glycol-based, non-aqueous heat transfer fluids, the views regarding additives were: (1) no recognition or discussion of using additives; (2) at least pH control additives were required, or (3) use of additives, including pH control additives, to address the concern of water entering the heat transfer fluid and causing corrosion.

9. These views resulted in various approaches to the use of glycol-based, non-aqueous heat transfer fluids prior to the disclosure of the present invention that resulted in either omission of important additive ingredients or including inappropriate additive ingredients that require water to be present in the heat transfer fluids.

10. For example, some tests of propylene glycol based heat transfer fluids were performed without any corrosion additives present in the fluid, such as those described in Coughenour and Dingley.

11. In other cases, as described for example in Reny, concern about pH caused the inclusion of pH control additives, such as phosphoric acid buffers. For phosphoric acid to

function in a manner as to affect pH, water must be included in order for the phosphoric acid to ionize. The action of the phosphoric acid creates phosphates that further require water for the phosphates to be in solution. Below a minimum amount of water, the phosphates will not remain in solution and will drop out as solids that can plug heat exchanger passages.

12. In still other cases, as described for example in Mascioli, Greaney and Wood (in antifreeze concentrates that have been incorrectly treated by the Examiner as non-aqueous heat transfer fluids), the heat transfer fluids include water soluble (but non-glycol-soluble) additives, such as sodium metasilicates, that require the presence of added water to dissolve the additives so as to enable them to perform their function.

13. Contrary to the descriptions in these and other references, I recognized that when the water content is very low, the pH of the fluid is immaterial, and that the heat transfer fluid must avoid all additives that cannot function without water.

14. The heat transfer fluids claimed in the present application do not include any additives that require water in the heat transfer fluid to dissolve or to perform their function.

I, the undersigned, declare further that all statements made herein are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date: March 5, 2007

John W. Evans

John Evans

EXHIBIT 3

Chemical Sampling Information:

Sodium Metasilicate

General Description

Synonyms: Silicic Acid (H2Si03) Disodium Salt; Crystamet; Disodium Metasilicate; Disodium Monosilicate; Orthosil; Metso Beads, Drymet; Sodium Metasilicate, Anhydrous; Sodium Silicate; Water Glass

OSHA IMIS Code Number: S245

Chemical Abstracts Service (CAS) Registry Number: 6834-92-0

NIOSH, Registry of Toxic Effects (RTECS) Identification Number: VV9275000

Chemical Description and Physical Properties: Usually obtained as a glass; also orthorhombic crystals. Usually prepared from sand (SiO2) and soda ash (NaCO3) by fusion. Soluble in cold water, hydrolyzed by hot water. Insoluble in alcohol, acids, salt solutions.

molecular formula: $O_3Si{\bullet}2Na$
molecular weight: 122.07
melting point: 1089°C

Health Factors

Health Effects: Severe skin irritation; inhalation of dusts can irritate upper respiratory tract.

Monitoring Methods used by OSHA

Laboratory Sampling/Analytical Method:

- **note:** Call SLTC for instructions.

* All Trademarks are the property of their respective owners.

Occupational Safety & Health Administration
200 Constitution Avenue, NW
Washington, DC 20210

Page last updated: 04/19/2005

EXHIBIT 4

AQUEOUS AND NON-AQUEOUS ENGINE COOLANTS BASED ON PROPYLENE GLYCOL

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1 INTRODUCTION

Engine coolants form a vital function in most internal combustion engines. The reason for this is that only about a third of the energy liberated by burning fuel is used to generate motive power, another is dissipated in the exhaust and the rest heats the metal of the engine. This paper discusses the use of monopropylene glycol (MPG) as the antifreeze component of a modern coolant and briefly summarises the HYBRID™ system in which the entire coolant is MPG.

2 CHARACTERISTICS OF ENGINE COOLANTS

If the heat generated in the metal of the engine were not removed, the engine would finally seize as the lubrication system failed. The main function of the cooling system, therefore, is to transfer heat from the metal of the engine to the radiator so that it can be safely dissipated to the atmosphere. To carry out this function the fluid should have a high specific heat, be liquid over the entire operating range of the engine, have a high boiling point and low freezing point, it should not corrode the metals of the engine, it must be chemically stable, it should not be flammable or toxic and of course it should be readily available and inexpensive.

No single material can satisfy all these demands but fortunately water comes closest with high cooling power and good heat transfer characteristics.

Unfortunately, it also has several deficiences. In particular it freezes at too high a temperature and boils at too low a temperature and in the presence of air, it is highly corrosive to metals.

To overcome the high freezing point, most people know that a glycol is dissolved in the coolant water but in a commercial antifreeze concentrate, there can be up to ten other ingredients which act to prevent corrosion of the metals of the engine and reduce the degradation of the glycol. With the increased performance of modern vehicle engines, manufacturers are developing more stringent requirements for the coolants and furthermore there is increased awareness of the need to use safe, non-toxic products whenever possible in any industrial or consumer environment. For these reasons MPG is being increasingly considered, not only as a viable antifreeze product, but as the preferred product where high performance and safety to the public are concerned.

3 PROPYLENE GLYCOL AS AN ANTIFREEZE

Since the main function of the glycol is to reduce the temperature at which the fluid ceases to function, it is instructive to compare the freeze point of ethylene glycol (EG) and MPG solutions in water at various concentrations. Figure 1 shows the freeze point measured using ASTM D-1177 for volume concentrations of glycols from 0 to 60%. The difference in freeze point measured by this method is about 2.5 C over the useful range of concentrations. The range bars on figure 1 show the range of values obtained when the same MPG solutions were tested by two different operators using three different examples of a density freeze point tester calibrated for MPG. It can be seen that the range is up to ±3 C indicating that the accuracy of measurement is within the difference of freeze temperature of the two glycol solutions. Furthermore, there are few places in Europe where protection to greater than -30 C is required so that normal glycol concentrations of 50% would provide adequate freeze protection for most circumstances.

For these reasons there is generally no need for the concentration of MPG based antifreeze solutions to be any greater than EG systems unless exceptional conditions are expected when higher concentrations may be used without difficulty.

4 CORROSION BEHAVIOUR

Corrosion protection of metals in an engine is very largely determined by the inhibitors used in the coolant mixture. However, the type of glycol does have

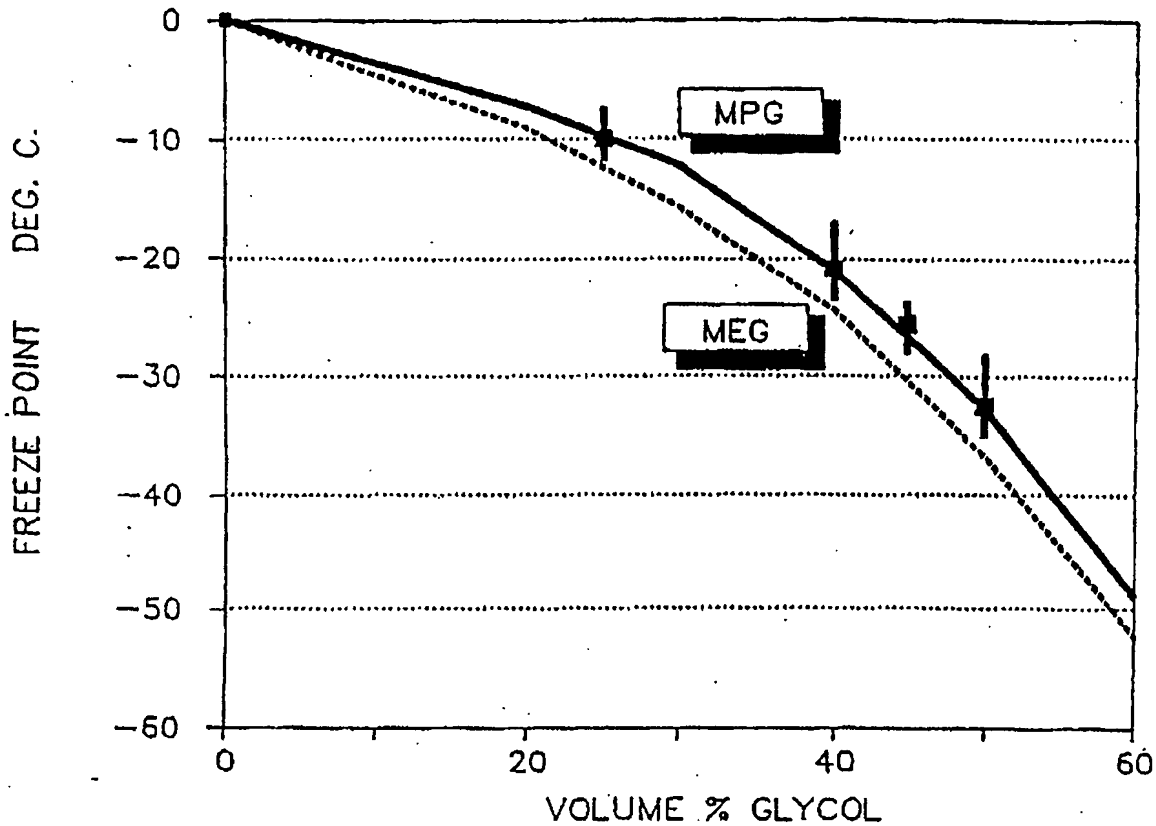

FIG. 1 – Showing ASTM D-1177 Freezepoint as a function of Glycol Concentration

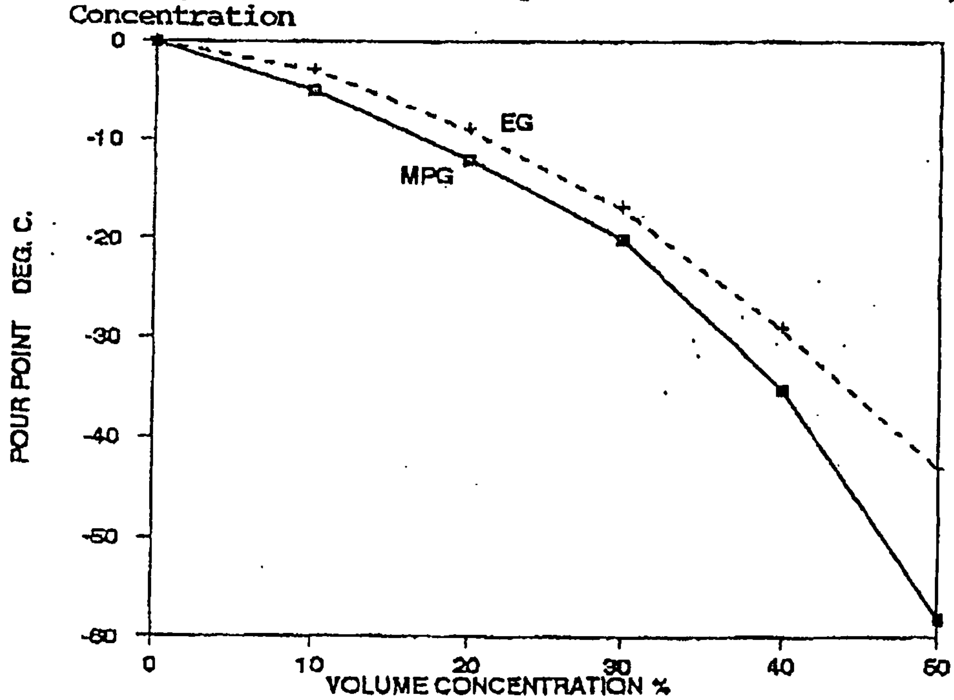

FIG. 2 POUR POINT OF MPG AND EG SOLUTIONS

a significant effect on the type of corrosion caused by cavitation of the coolant and which results in severe pitting of metal surfaces. This problem is particularly severe on the wet cylinder liners of heavy duty diesel engines and on the impellers of some water pumps.

In both laboratory and engine tests comparing the two types of glycol, MPG has been shown to give a significant improvement in protecton against cavitation corrosion of cast iron and aluminium. Hercamp, Hudgens and Coughenour[1] carried out laboratory tests using a cast iron probe vibrating at 20 kHz and 1.25 x 10^{-3} amplitude to generate cavitation conditions in 15% commercial coolant solutions. They compared the weight loss after 6 days at 71 C for EG and MPG based systems both with the same inhibitor package. Their results indicate a clear advantage for the MPG based system which resulted in a weight loss of only 6.3 mg compared with 23 mg for the EG coolant.

The results from these tests were confirmed in running a modern, high powered diesel engine on a dynamometer where the MPG coolant was shown to eliminate completely any pitting of the cylinder liners. They concluded that the use of MPG provides extra cavitation corrosion protection equivalent to at least 20 to 40% more than the inhibitors in a conventional formulation. Other points to emerge from these tests were:

a) engine temperature, fuel consumption and other performance parameters were similar for both systems,
b) MPG is more resistant to oxidative degradation than EG and the coolant may therefore last longer,
c) there is a reduction in the corrosion of aluminium when tested under heat rejection conditions (ASTM 4340).

5 SAFETY AND ENVIRONMENTAL ISSUES

There are increasing demands from consumers for safer and environmentally acceptable products to replace those which are either dangerous or pollute the atmosphere. This is particularly strong for chemicals which have a generally poor image in the consumers' mind. If safer alternatives exist, therefore, it must be right to use them. It is in this respect that MPG shows an important benefit over EG.

EG is classified by the FDA and the EEC authorities as harmful and as a result is subject to OSHA and COSHH regulations. In the EEC any antifreeze made with EG has to carry the St Andrew's cross indicating it to be a dangerous product. This is no scare story as there are recorded instances of human deaths

from drinking antifreeze. In the USA over 50% of all deaths from poisoning of cats and dogs are attributed to EG. The American Occupational Safety and Health Administration requires that exposure to EG does not exceed 50 ppm. This value was "Based on evidence of an occupational risk of severe throat and respiratory irritation". In the EEC the limit is 60 mg m^{-3} for vapour and 10 mg m^{-3} for a mist of suspended particles with a maximum of 125 mg m^{-3} over a ten minute period. In contrast, MPG is classified as "Generally Regarded as Safe" by the FDA and is widely used in petfoods, cosmetics and detergents as well as being an antidote for EG poisoning.

In recognition of this difference in toxicity, the Swiss Poison law of 1972 banned the sale of EG antifreeze in supermarkets, shops and generally across the counter to the public. Austria introduced a similar law in 1989 after problems with poisoning from EG in wine. For this reason MPG antifreeze concentrates are widely used in these countries and have given no problems.

MPG is readily biodegradable and is classified as relatively harmless to freshwater and marine algae, invertebrates and fish according to a toxicity rating of the US Fish and Wildlife Service. It has no known detrimental affect on the environment.

ARCO Chemical Company is a leading world wide producer and supplier of propylene glycols with factories in Europe, Asia and the USA and sales organisations in all major markets. MPG is a world scale commodity chemical with current capacity approaching 1 million tonnes. Availability is therefore no problem.

MPG based coolants are available now and have gained wide acceptance in Italy as well as Switzerland and Austria. The growing awareness of the advantages it affords, from both a technical and safety point of view, will ensure it is used more extensively in future. After all:- *if there is a safer alternative available, why not use it?*

Missing p. 148

6 NON-AQUEOUS OR HYBRID™ COOLANT SYSTEMS

No discussion of MPG based engine coolants can be complete without some mention of a very interesting development where all water is eliminated from the system. Such a system has been developed over the last ten years by Jack Evans of MECA Developments Inc. and Tom Light of National Technologies Inc. in the USA. This subject merits a whole paper to itself as indeed the above gentlemen have presented to many distinguished audiences. However, this paper summarises the most important aspects of the system. To understand the

reasoning behind the idea it is necessary to review the mechanism of heat transfer from the engine to the cooling system and subsequent dispersion.

There are two principal mechanisms at work; convection and nucleate boiling. Convection is the mechanism operating in the radiator and to some extent in cooling the engine block in the cooler areas. The efficiency obviously depends upon the specific heat, conductivity and viscosity of the medium; water is very good in this respect.

When the temperature of the metal approaches the boiling point of the cooling fluid localised vaporisation occurs at the interface between the metal and the fluid followed by immediate condensation of the vapour in the bulk fluid. This vaporisation and condensation (referred to as nucleate boiling) transfers very high quantities of heat to the fluid since, of course, the heat of vaporisation of a liquid is much higher than the specific heat.

Problems arise with this method of heat transfer when the engine operating temperature is close to the boiling point of the coolant for a given pressure. Under these conditions the vapour cannot condense efficiently and vapour accumulates at critical areas of the interface causing a vapour blanket and catastrophic reduction in heat transfer. Other problems result from flash vaporisation in the water pump causing loss of fluid circulation. After boil is also likely after the engine is shut down and residual heat dissipates into stationary coolant. For these reasons water based systems have to run at relatively low temperatures or under pressure to increase the boiling point.

Jack Evans conceived the idea of replacing water with a fluid having a much higher boiling point than water but which also had good heat transfer characteristics and did not freeze under normally encountered conditions. After considering a number of alternatives he concluded that MPG showed the best overall properties for his purpose. Some properties of MPG and a 50/50 mixture of EG and water are shown below:

Property	MPG	50/50 EG/water
boiling point	187	107
freezing point	-57	-37
heat of vaporisation (kcals mole^{-1})	12.5	9.8

The much higher boiling point and lower freezing or pour point of MPG are evident advantages. The high boiling point achieves the objective of a large

point depressant in automotive coolants. It has distinct safety advantages over EG and technical advantages especially when used in heavy duty engines.

The complete elimination of water in engine coolants by using 100% MPG has already proved beneficial in high powered racing engines. With the drive towards longer lasting sealed coolant systems, this may well be the preferred method for all cars of the future.

8 ACKNOWLEDGEMENTS

I should like to thank ARCO Chemical Company Inc. for permission to publish this paper and my colleagues, Glen Coughenour, Bill Weeks and Jim Greaney for help in its preparation.

REFERENCES

1. Hercamp, Hudgens and Coughenour, 'Aqueous Propylene Glycol Coolant for Heavy Duty Engines', Proc. Int. Congress, Detroit, 1990, SAE Techical Paper SP 811-900434.

EXHIBIT 5

PREVENTING COOLING SYSTEM PROBLEMS

Preventing Cooling System Problems with the Penray Fill-For-Life Program

Industry experts estimate that about 40% of engine downtime is caused by cooling system problems. Understanding the common problems and implementing proven preventative maintenance practices allows fleet managers to significantly reduce their operating costs. Cooling system engineers have specific terms that they use to discuss cooling systems, their components, and system maintenance. Some of these terms are listed in the Glossary.

The four major problems relating to cooling systems are:
• Corrosion
• Cavitation-erosion
• Scale deposits
• Green-goo or drop-out

The first three of these problems are discussed, in detail, in other sections of the Cooling System TechFacts. However, we are happy to report that the fourth, ìGreen-gooî or ìdrop-outî, has nearly been eradicated by the introduction of low-silicate, phosphate-free fully-formulated antifreeze. Silicate and phosphate, while valuable as corrosion inhibitors in engine coolant, have limited solubility. That meant that if the antifreeze or additives got too concentrated in the coolant, then the excess phosphate and/or silicate would "drop-out" of the coolant. These "drop-out" problems caused premature water pump failures, radiator blockages, heater core problems and were a headache to clean up. About ten years ago, phosphate-free coolant was introduced. Combined with technology that permitted the reduction of the silicate concentration, this new inhibitor technology has eliminated annoying and costly drop-out complaints for Penray customers.

The practice that Penray customers have found successful is remarkably simple. Most new coaches and new Freightliner, Peterbilt and Kenworth trucks come with Fill-For-LifeÆ technology from the factory. Simple installation of a Need-ReleaseÆ filter begins the Fill-For-Life program.

Older vehicles can be easily converted to Fill-For-Life programs, too! All that is required is the draining of the old coolant, a simple water flushing of the cooling system, and refilling with fully-formulated coolant. The simple installation of a Need-Release filter finishes the Fill-For-Life conversion.

Fill-For-Life programs have been developed for all types and sizes of engine applications. Contact your Penray representative for details on the Fill-For-Life program that's right for you!

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EXHIBIT 6

930584

Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines

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ARCO Chemical Co.

L. K. Hwang
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ABSTRACT

Five different engine tests utilizing non-aqueous propylene glycol as the engine coolant were run to examine various aspects of durability and engine performance. This paper reports the results of these engine and bench tests designed to quantify the effects on performance and engine durability. Comparisons are made to baseline engine tests using 50 % aqueous ethylene glycol coolant. Also reported are the data necessary to determine the effects on the size and design of related heat exchangers.

Based on these test results, some of the presumed advantages and disadvantages of the use of non-aqueous propylene glycol engine coolants (1)* have been quantified. This work is useful as a basis for further work using total-vehicle systems taking advantage of this innovative technology.

INTRODUCTION

An internal combustion engine must have an effective means of rejecting the energy liberated that can not be recovered as work. This is the function of the cooling system, the main component being the coolant fluid. The choice of this coolant directly affects the durability and performance of the engine.

Glycol/water mixtures are generally used for this service. They work rather well for heat rejection, but their limitations make a more advanced coolant desirable. Water is one of the best convective heat transfer media available, but because it is also a great solvent its presence leads to corrosion issues. This can be managed with inhibitor technology, but this is cumbersome and expensive. In heavy duty applications where long life is an important design criterion, cast aluminum is not used in contact with coolant because adequate component life can not be achieved. If water were not used, lower cost aluminum castings could be used without sacrificing engine life expectancy.

* Numbers in parentheses designate references at end of paper.

Another serious problem results from the low boiling point of water. Localized boiling will occur inside the cooling channel if the local temperature exceeds the coolant boiling point. Although boiling is the most effective means of enhancing heat transfer, problems arise if the vapor is not removed as fast as it is generated. If the vapor is not swept away by coolant flow, or if the heat flux from the metal is too high, the nucleate boiling phase will change to a film boiling phase, forming a layer of vapor on the metal surface. This vapor blankets heat transfer and the burn-out point is reached. This condition generally leads to engine failure. Pressurizing the cooling system raises the boiling temperature, but adversely effects the safety and durability of the cooling system. Burns from opening the cooling system of an overheated engine, or just one that has recently been shut down, are a serious hazard.

When a heavily loaded engine is stopped, the coolant circulation stops resulting in subsequently low heat transfer rates. If the coolant has a low boiling point, vapor blanketing can occur at hot spots. If the engine is restarted under this condition, scuffing can occur because of inadequate cooling.

The vapor bubbles formed from low boiling point coolants are also known to result in cavitation damage to cylinder liners and coolant pumps. This problem can be reduced with supplemental coolant additives, but it is costly and tedious to assure that balanced chemistry is maintained.

A water-free, or non-aqueous, system, is thus desirable.(2) One such system has been patented by Evans Cooling, Sharon, Connecticut. (3)(4) The system uses a neat or undiluted propylene glycol engine coolant.(5) This evaluation of the -694 patent, as adapted to a Cummins diesel (slow-flow with condenser), verifies concern for the lower convective heat transfer characteristics of the non-aqueous coolant and resultant higher metal temperatures as well as concerns regarding viscosity differences, of the coolants, and the possible need for increases in heat exchanger frontal area. A subsequent Evans' patent,(6) patents pending, and application experience address and correct these deficiencies. The

improvements warrant consideration for any future testing or application of the cooling technology.

Propylene glycol is attractive as a heat transfer fluid because it has a low freezing point (-70°F), high boiling point (369°F), low corrosivity, low toxicity, is biodegradable, is readily available in adequate quantities, and is reasonably priced.(7) Compared to a glycol/water solution, neat glycol has some drawbacks as heat transfer fluids that require study to judge the merit of such an innovative cooling system.

Specifically, the convective heat transfer coefficient predicted for neat glycol is much lower than that of a glycol/water solution.(8) Figure 1 shows a plot of the Sieder & Tate relationship (9) for a series of fluids ranging from water to SAE 15W-40 lubricating oil. As can be seen, adding glycol to water reduces this coefficient by more than half. Neat propylene glycol is nearly the same as diesel fuel. The lubricating oil is the poorest of these fluids. The viscosity of propylene glycol also raises some fluid flow concerns in areas of high pressure drop such as the heater circuit of an on-highway truck.

Figure 2 reflects these heat transfer differences for ethylene glycol/water, propylene glycol/water and non-aqueous propylene glycol coolant on the effectiveness of the radiator. On average the undiluted glycol reduces the effectiveness by 20%.

A conclusion regarding the value of a non-aqueous glycol coolant can not be reached without some empirical study of all these effects combined. Such an evaluation program was conceived to accomplish that.

COOLANT EVALUATION PROGRAM

An extensive program was executed to gauge the effects of using neat propylene glycol coolants on the performance of a heavy duty engine. For the purpose of this study, the cooling system flow pattern was not altered, i.e. the coolant returning from the radiator entered the coolant pump, oil cooler, the aftercooler, the lower section of the cylinder cooling jackets, cylinder head and exited from the upper chamber of the water header to the radiator. There were some alterations employed to isolate specific effects that will be described as those analyses are presented.

The work was done with a Cummins L-10 six cylinder turbocharged diesel engine of an experimental 1991 configuration.

After chassis dynamometer runs confirmed that neat propylene glycol coolant would function adequately in this engine, a test cell dynamometer program commenced which evaluated the engine performance and heat balance over a matrix of operating conditions. A 500 hour durability test, emissions testing, and a cold start white smoke test followed. The effects of the neat propylene glycol coolant on commonly used elastomers were evaluated in parallel laboratory work.

CHASSIS DYNAMOMETER RESULTS - The initial testing of propylene glycol as an engine coolant was done by the application group of the Cummins Engine Company. An L-10 engine equipped with a low flow cooling system (OAC) was installed in a truck to be run in a wind tunnel on a chassis dynamometer. A four-by-two test matrix was run. Water, a 50/50 mixture of ethylene glycol and water, a 50/50 propylene glycol and water, and 100% propylene glycol were used as coolants while the engine was run at two different conditions: 1800 RPM / 100 lb/hr fuel rate and 1300 RPM / 78 lb/hr fuel rate. The results are shown in Tables 1 and 2, and Figures 3 and 4. It is clear that while there is no significant difference between the two aqueous solutions, the 100% PG coolant requires lower ambient (air side) temperature to achieve the target top tank temperature. Oil temperature and the cylinder liner temperatures are higher, indicating the expected poorer heat transfer in the convective regime.

Although non-aqueous propylene glycol has some detriments when used in a system configured for an aqueous mixture, it did work well enough to warrant further investigation in the controlled environment of the dynamometer cell.

TESTING PROGRAM - A 1991 L-10 prototype engine was used for this program. The engine configuration was:

Rating:	330 HP @ 1800 RPM
Torque Peak:	1150 ft-lbs @ 1200 RPM
Fuel System:	PTD fixed timing
Camshaft:	Rate control cam P/N 3053006
Compression Ratio:	16
Turbocharger:	Holset H2D 9351/1903

The engine was assembled at the Cummins Technical Center and shipped to Engineering Test Service in Charleston, South Carolina for installation in a dynamometer cell.

Computerized data gathering was used with extensive instrumentation to measure performance, temperatures, and pressures. The engine operating parameters collected during the test include:

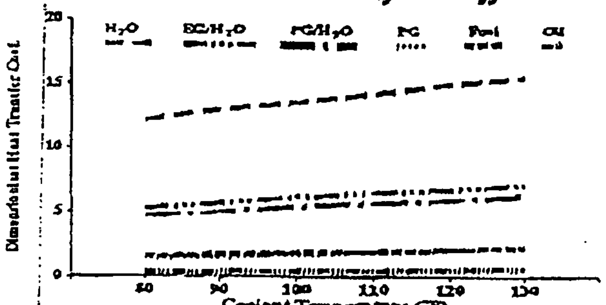
Engine Parameters:	Engine Speed, Engine Torque, Fuel Rate, Smoke (BSU), Air Flow
Temperatures:	Coolant Inlet, Coolant Outlet, Oil Pan, Fuel Inlet, Intake Manifold, Crossover, Exhaust, Turbine Inlet, Stack, Cell (Ambient)
Pressures:	Inlet Restriction, Intake Manifold, Turbine Inlet, Crossover, Stack, Blowby, Coolant Pump Discharge, Oil Rifle, Fuel Rail, Coolant Pressure, and Barometric Pressure (Cell)

The following special instrumentation was used:

CYLINDER HEAD TEMPERATURE MEASUREMENT - The exhaust and intake valve bridges of cylinders #1 and #6 were fitted with thermocouples as shown in Figure 5. Grooves were machined 0.070 inch deep on the firing deck surface to get temperature measurement as close to the cylinder

Figure 1

Working Medium Property Impact on Convective Heat Transfer Coefficient



Note: Sieder & Tate Correlation

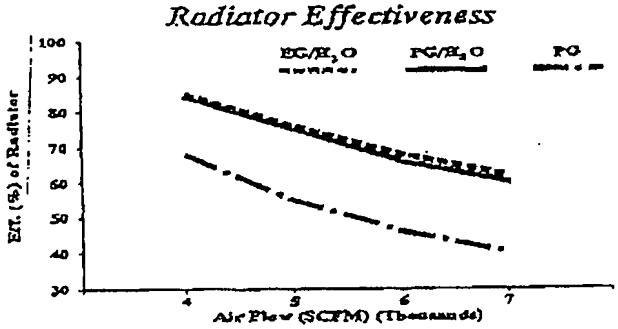
Table 2

Chassis Dynamometer Test Results

1300 RPM	Coolant			
	Water	EG/Water	PG/Water	PG
Ambient Temp(°F)	110	106	106	88
Top Tank ΔTemp (°F)	90	95	94	119
Bottom Tank ΔTemp (°F)	40	39	40	39
Avg. Cylinder Liner (°F)	316	343	349	406
Oil Temperature (°F)	230	243	245	289
Fuel Rate (lb/hr)	78.1	79.2	78.1	76.3

Figure 2

Coolant Impact on Radiator Effectiveness



Note: Coolant Flow Rate 100 GPM, Coolant in 210 °F, Air in 106 °F

Figure 3

Chassis Dynamometer Test Results at 1800 RPM

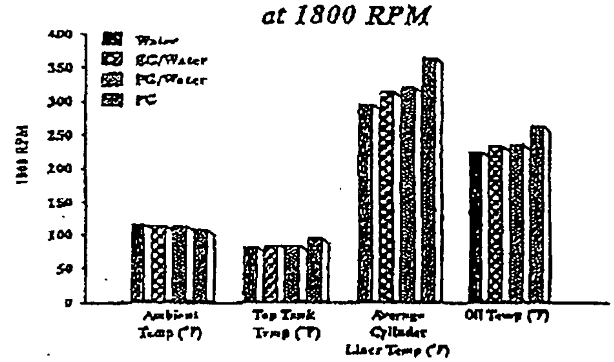


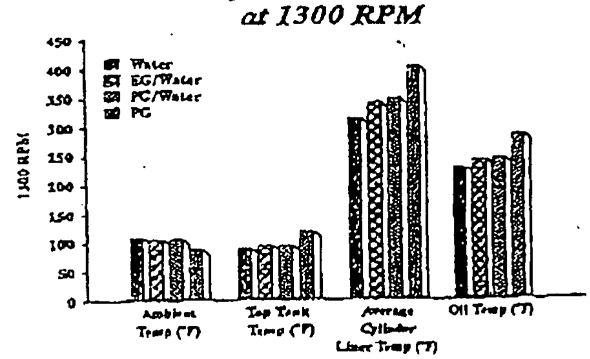
Table 1

Chassis Dynamometer Test Results

1800 RPM	Coolant			
	Water	EG/Water	PG/Water	PG
Ambient Temp(°F)	117	114	114	107
Top Tank ΔTemp (°F)	82	85	84	95
Bottom Tank ΔTemp (°F)	41	40	40	43
Avg. Cylinder Liner (°F)	298	316	322	366
Oil Temperature (°F)	226	234	237	265
Fuel Rate (lb/hr)	101.3	98.1	100.3	97.0

Figure 4

Chassis Dynamometer Test Results at 1300 RPM



head surface as possible. After the thermocouples were laid in the grooves, the cylinder head was resurfaced. These two pairs of thermocouples allowed the measurement of the greatest temperature differential across the cylinder head.

CYLINDER LINER TEMPERATURE MEASUREMENT - The #3 cylinder liner was machined on the outside diameter and twelve thermocouples installed as indicated in Figure 6. Four were placed at ninety degree intervals around the circumference at the top ring reversal height, the bottom ring reversal, and at an intermediate point.

MEASUREMENT OF HEAT REJECTION -The total coolant heat rejection and the oil cooler heat rejection were measured using venturi tube flow meters and precision thermocouples.

To isolate the coolant as the sole test variable, the oil cooler was separated from the engine cooling loop and provided with an independent temperature control. The oil temperature was maintained constant at 230°F. Similarly, the fuel temperature was maintained at 100°F.

In order to minimize the coolant pump inlet pressure, the coolant makeup tank was lowered as much as possible while preventing coolant from flushing back. A condenser was fitted to the tank vent to recover any vapor that might occur in the system if there were boiling.

TEST MATRIX - A five by four by two test matrix was run to gather the above operating data over a range of engine operating speeds from 800 RPM to 1800 RPM, engine loads at 50% and 100%, and coolant variations beginning with an aqueous ethylene glycol baseline at 180°F coolant outlet temperature, then changing to non-aqueous propylene glycol with a coolant outlet temperature at 180°F, 200°F, 220°F and 240°F. Energy balances were done for each coolant variable. Heat exchanger sizing calculations were done for each as well.

DURABILITY TEST - The instrumented engine was run on the dynamometer at rated conditions for 500 hours. In addition to the data prescribed in the test above, oil degradation, oil soot loading, oil consumption, ring wear, cylinder liner wear, piston land carbon deposit, elastomer compatibility, and coolant degradation were monitored either by sampling during the test or inspection upon disassembly at the test completion.

EMISSIONS TESTING - Steady state emissions testing was done at a coolant outlet temperature of 230°F for propylene glycol and compared to baseline run on ethylene glycol water at 180°F. Prior work suggested that higher temperature reduced particulate emissions.(10)

COLD START WHITE SMOKE TEST - This was done with the engine operating on propylene glycol and ethylene glycol/water for direct comparison. The engine was soaked overnight at 32°F before the coldstart test was performed. Hydrocarbon emissions were tracked during the test.

BENCH TESTING OF ELASTOMER COMPATIBILITY - The various non-metallic engine materials were tested for compatibility with ethylene glycol/water, propylene glycol/water, and propylene glycol on a rig test in a 257°F temperature bath. Nitrile rubber, silicone rubber, ethylene propylene rubber, and Viton were checked for compatibility by measuring tensile strength, elongation, compression set, swell, and Shore hardness changes at one week and three weeks of immersion in the coolants. (11)

1000 HOUR THERMAL CYCLE TEST - The engine was run through a 1000 hour operating cycle on a dynamometer. This test has been developed by Cummins as an accelerated method to check component life in new designs. The engine is over-stressed relative to its rating in operating speed, fuel-rate, and operating temperature to reveal weaknesses.

DISCUSSION OF TEST RESULTS - Generally the engine ran well on the non-aqueous propylene glycol coolant. There were several observations consistent with the poorer heat transfer characteristics of undiluted glycol and the higher coolant temperatures used in the test.

As the coolant temperature was increased, the efficiency of the engine was unchanged. The heat rejection via the coolant was reduced significantly. About a quarter of that decrease appears attributable to the lower heat transfer coefficient of undiluted glycol and the balance due to reducing the temperature differential between the combustion chamber and the coolant. Since the engine was not modified to capture this reduction in energy loss, it was just transferred to the exhaust and the oil cooler. (Figure 7)

Engine metal temperatures changed as a result of the tested coolant changes. At the rated engine condition, the change in coolant from aqueous ethylene glycol to non-aqueous propylene glycol resulted in cylinder liner temperature increases of 14°F for the highest liner temperatures and 21°F for the lowest. Thereafter, increasing the coolant temperature increased these further at a rate of 0.5 to 0.7°F per 1°F coolant temperature change. (Figure 8)

At the torque peak, the coolant change resulted in liner temperature increases of 25°F for the maximum temperatures and 20°F for the minimum. Coolant temperature increases resulted in liner temperature increases at the same rate as at the rated condition. (Figure 9)

The cylinder head temperatures increase also. At the rated condition, changing the coolant to non-aqueous increases the intake valve bridge temperature by 15°F and the exhaust valve bridge by 30°F. Coolant temperature increases are again reflected at a reduced rate, 0.6°F per 1°F coolant temperature change. (Figure 10)

At the torque peak, changing to non-aqueous coolant increases the intake valve bridge by 18°F and the exhaust by 45°F. The intake side increases 0.8°F per 1°F in coolant temperature change, but the exhaust side increased at 0.75°F per 1°F coolant change. Clearly the reduction in convective heat transfer resulting from removing the water from the coolant is more greatly reflected in the cylinder head with its high heat flux. (Figure 11)

RADIATOR AND OIL COOLER ANALYSIS - The total engine heat rejection via the radiator and oil cooler was plotted against the coolant variables in Figures 12. As noted previously, changing from

Figure 5

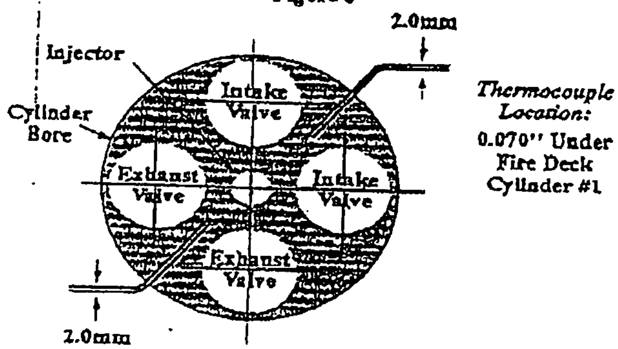


Figure 8

Liner Temperature at Rated Condition

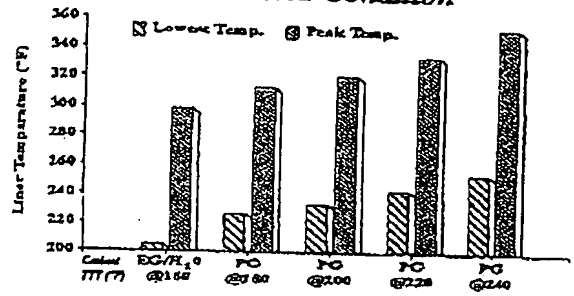


Figure 6

L10 Cylinder Liner Thermocouple Locations

(millimeters)

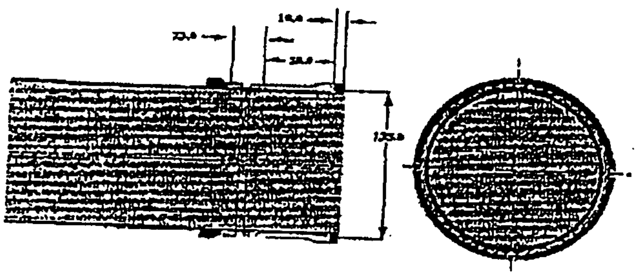


Figure 9

Liner Temperature at Torque Peak

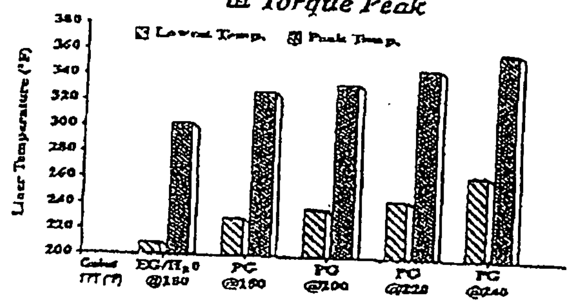
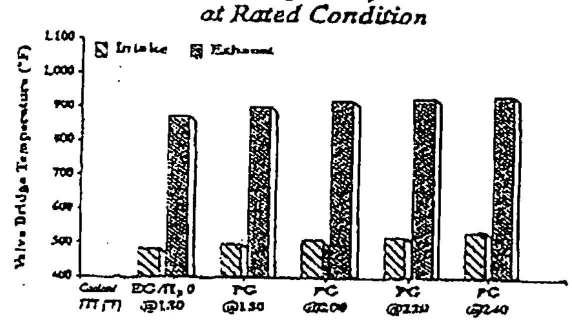


Figure 7

Engine Heat Balance @ Rated Conditions for Tested Coolants & Temperatures

Figure 10

Valve Bridge Temperature at Rated Condition



aqueous ethylene glycol to non-aqueous propylene glycol reduces the heat transferred through the coolant and increases the heat transferred through the engine oil . The data collected indicates that the total heat rejection increased, but this appears to be an artifice of the test since there is no theoretical reason why this should happen. As the coolant temperature is raised, the radiator heat load is reduced and the oil cooler load increased, but the total load decreases. Furthermore, as the coolant temperature is increased the area required for heat transfer of course decreases.

All of this information was evaluated by the McCord Heat Transfer Corporation who sized the radiator and air-cooled oil cooler for each coolant variable point. An air-cooled oil cooler was specified because an oil temperature of 230°F was needed to continue the use of conventional engine oils This could not be done with coolant temperatures above 200°F. As can be seen in Figure 13, the higher temperatures permit the use of a radiator and oil cooler that are approximately equal size and have less than 75% of the required frontal area as needed for the radiator in the ethylene glycol/water base case However, simply changing from ethylene glycol/water to non-aqueous propylene glycol at normal operating temperature increases the radiator size required by almost 15%.

EFFECT ON COLD START EMISSIONS - A Cummins L-10 engine with electronically controlled fuel injection was soaked in a cold test cell at 32°F. The test protocol is to start the engine and let it idle while measuring its hydrocarbon emissions as a function of time. Figure 14 shows the results of the test run on EG/water and on non-aqueous PG. In the PG case, the coolant and oil temperatures both increased more rapidly, but there was no apparent reduction in the hydrocarbon emissions. The electronic control does such a good job that the faster warmup has little effect on emissions from cold starting.

EFFECT ON STEADY STATE ENGINE EMISSIONS - To determine if non-aqueous propylene glycol coolant would have any effect on engine emissions, a steady state simulation (Figure 15) of the EPA Transient Emission cycle was run on EG/water at 180°F and PG at 240°F. The engine was modified to isolate the oil cooler and the intake manifold temperature was held constant at 125° F. Figure 16 summarizes the results. Although the hydrocarbon emissions seem to be higher with PG the difference is within the measurement error at these low levels.

EFFECT OF NON-AQUEOUS PROPYLENE GLYCOL ON ENGINE ELASTOMERS - The results of the parallel tests run with EG/water, PG/water, and non-aqueous PG on typical elastomers used were (Table 3):

1. The performance of silicone, Viton, nitrile, and EPDM rubbers were not affected by substituting PG for EG in a 50% aqueous solution with Fleetguard DCA4 additive added.
2. Nitrile rubber swelled about 40% in non-aqueous PG. Its compression set was not significantly changed The high swell may be detrimental to elastomer parts such as the coolant pump bellows seal and some crevice seals.
3. EPDM performed well in all PG solutions.
4. Viton displayed the same surface cracking in PG/water and non-aqueous PG as it does in EG/water.

500 HOUR ENDURANCE TEST - The L-10 engine was set up to operate at 330 BHP and 220°F coolant outlet temperature. Cummins Premium Blue oil was used and oil temperature held at 230°F. Oil samples were drawn every 50 hours for analysis. After 250 hours there appeared to be no apparent deterioration, so the coolant outlet temperature was increased to 240°F to accelerate the test.

The fuel rate and BSFC were both reasonably stable throughout the test and the oil pressure held steady at 35 psi. Exhaust stack temperature increased slightly with the coolant temperature. Oil consumption was very low. There was no increase in oil deterioration when the oil analyses were compared to reference analyses of oil samples taken at similar conditions except with standard coolant conditions. This is not surprising since the oil sump was held at normal temperature, but it does indicate that no surfaces became hot enough to "crack" the oil when using propylene glycol coolant.

Upon disassembly, a few parts indicated the need for changes for continued operation at higher coolant temperatures. Some of the gasket and seal materials were hardened, indicating the need of more robust materials. The pistons and piston rings showed some abnormally high wear, indicating that a different type should be used at these higher temperatures. There was some polishing of the inside of the cylinder liners, indicating marginal cooling at some spots. In a favorable sense, the coolant system passages and other components including the coolant pump were in excellent condition. There was no evidence of pitting on the cylinder liners or the adjacent engine block walls. The cylinder head passages were very clean.

1000 HOUR THERMAL CYCLE TEST - The test cycle was taken from Cummins engine design experience, but modified to incorporate the coolant change and higher coolant outlet temperature. Figure 17 depicts the cycle. It begins with 5 minutes of 10% over-fueling at rated speed and engine coolant outlet temperature of 250°F. The next stage is 2 minutes of 10% over-speed at no load and the coolant temperature at 235°F. The last phase is 2 minutes of idling at 235°F coolant temperature. The cyclic thermal stressing of the engine on both load and speed is intended to reveal weaknesses.

During the test there was one failure that was attributable to the higher operating temperature Four of the six aluminum pistons cracked at the pin bore because of the higher combustion pressure and higher operating temperature after 496.5 hours. These pistons were replaced with new articulated pistons having steel caps and new rings, then the test was resumed. The last 500 hours were completed without incident.

Upon disassembly the coolant passages were in excellent condition. There was no evidence of pitting on the cylinder liners or the block walls. This is doubly significant because this particular engine block

Figure 11

Valve Bridge Temperature at Torque Peak

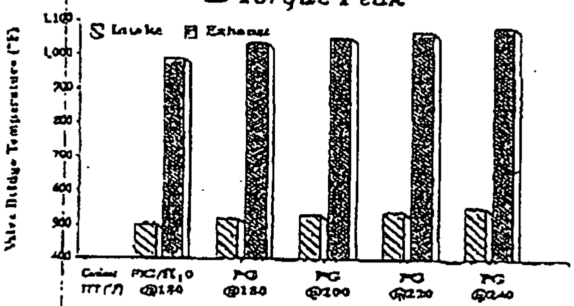


Figure 14

Coolant Impact on L10 Engine Cold Start

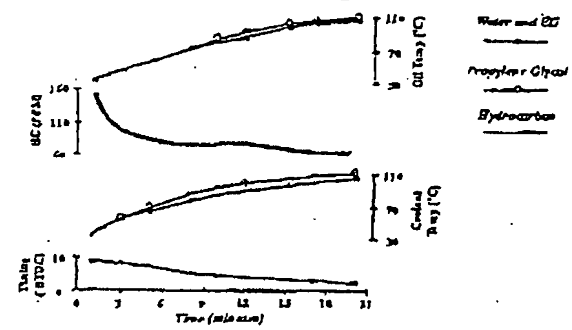


Figure 12

Heat Rejections with Various Coolants & Temperatures at Rated Condition

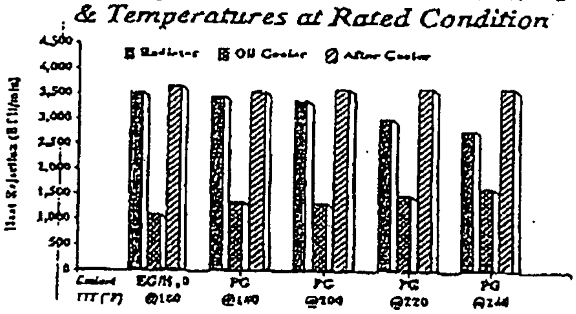


Figure 15

8-Mode Transient Cycle Simulation

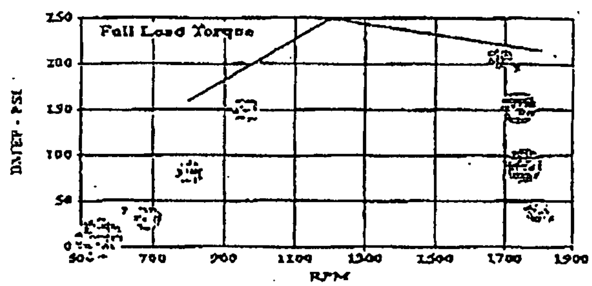


Figure 13

Radiator and Oil Cooler Sizes

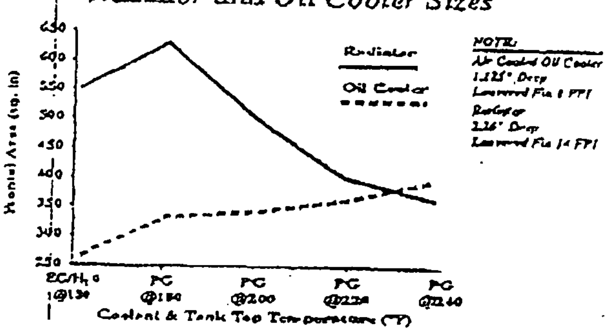
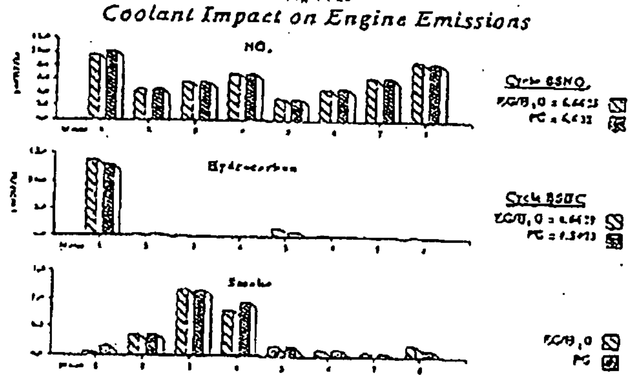


Figure 16

Coolant Impact on Engine Emissions



was a prototype L-10 configuration that had restricted coolant flow passages around the liner that promote liner pitting. In similar tests with conventional EG/water coolants, pitting was observed. The production L-10 configuration corrected this propensity. Although the test was not designed to evaluate the cavitation characteristics of PG coolant, it did bear witness to this quality of propylene glycol.

There was no indication of deterioration of the articulated pistons used in the last 500 hours, nor any indication of contact between the liner walls and the piston skirts or rims. Carbon and varnish buildup was normal. The connecting rod bearings had fatigue failure attributed to the high output of the engine for this test. Some of the gaskets and O-rings were hard and brittle after operating at higher temperatures. Oil analysis did not indicate any abnormal wear and coolant analysis showed no deterioration. There was some water found in the coolant samples which was traced to contamination of the makeup glycol.

SUMMARY AND CONCLUSIONS - Use of non-aqueous propylene glycol as the coolant in a production heavy duty diesel engine was thoroughly studied. In general this conversion is possible with some tradeoffs.

Non-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression. It also provides a greater margin of boil-over and vapor blanketing protection at a lower cooling system operating pressure. Cavitation damage in the coolant pump should be eliminated. Cooling system maintenance and chemical addition should be greatly simplified.

Non-aqueous propylene glycol does exhibit the reduced convective heat transfer predicted from its physical properties. At the same coolant temperature, theoretically this results in a need for larger radiator and oil cooler (if coolant used for oil cooling) than a glycol/water mixture requires. In actual practice, a larger radiator may be installed with glycol/water for overheating protection. In any case, heat exchanger sizes should be checked before coolant changes are made.

Within the range of temperatures studied, other than the possibility of reducing radiator size, there is no benefit to operating at higher coolant outlet temperatures. Engine efficiency and emissions are not significantly changed. The reduction in heat rejected via the coolant is offset by increased heat rejection via the exhaust and the oil cooler. The exhaust gas energy increase is too small to justify increased energy recover such as turbo-compounding.

Higher operating temperatures appear possible with relatively minor engine changes such as upgraded piston kits, different gasketing and seal materials, and higher performance lubricants. Although metal temperatures were increased in these tests, there was no evidence of increased failure rate in the cylinder head and other major components. This observation must be verified by long term statistical field failure tracking before propylene glycol would become an established coolant.

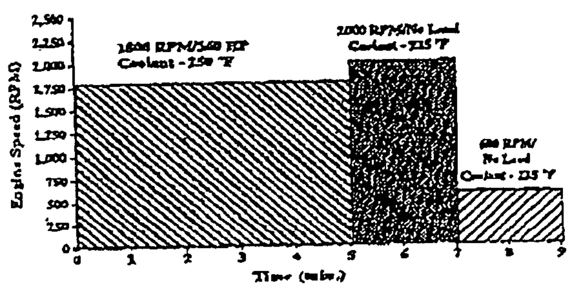
Changing from a glycol/water mixture to non-aqueous glycol requires evaluation of the elastomers used. The higher swell observed with nitrile rubber could be detrimental in some applications. EPDM performance is better without water contact.

In applications where boilover, cooling system corrosion, or coolant pump or cylinder liner cavitation are a significant problem, changing to non-aqueous propylene glycol may be a solution if done with the appropriate evaluation of the overall system. To achieve lower emissions or higher engine efficiency requires taking advantage of non-aqueous propylene glycol's higher operating temperature potential with modified engine designs.

It should also be noted that further developments have been made in this technology since this test program was conducted that address many of the issues identified in this work.

Figure 17

Nonaqueous Propylene Glycol Coolant
1000 Hr Thermal Cycle Test



REFERENCES

(1) Light. J. Thomas, "Hybrid Engine Cooling," A Presentation to the ASTM Committee D-15 on Engine Coolants, St. Louis, Missouri, October 6, 1987.
(2) Dawson, Dan; Flesher, Bob; Joyce, Bill Jr.; Kennedy, Tom; Kirk, Carl; Moffitt, Mike; Rood, George; Sullivan, John; Suski, Vic; Tylnk, David; "Tomorrow's Trucks: The Users Perspective-An Update;" SAE Paper 872243: November 1987.
(3) Evans, John W., "Process and Apparatus for Cooling Internal Combustion Engines," United States Patent Number 4,550,694, November 5, 1985.
(4) Evans, John W. and Light, J. Thomas, SAE Paper 861428, "Expanding the Limits on Engines and Vehicles Imposed by Circulating Liquid Engine Cooling Systems," September 1988.
(5) Remy, Greg P.; Titley, Guy L.; "Development of an Anhydrous Coolant for Automotive Applications," SAE Paper 9000432.
(6) Evans, John W., "Cooling System for Internal Combustion Engines," United States Patent Number 5,031,579, July 16, 1991.
(7) Coughenour, Glenn E.; Hercamp, Richard D.; Hudgens, R. Douglas; "Aqueous Propylene Glycol Coolant for Heavy Duty Engines," SAE Paper 900434, March 1990.
(8) Boyle, R.J.; Biddulph, T.; Finlay, I.C ; Marshall, R.A.; "Heat Transfer to Non-Aqueous Engine Coolants," SAE Paper 910304.
(9) Siedy, B.N., and Tate, G.E., "Heat Transfer and Pressure Drop of Liquids in Tubes," Ind. Eng. Chem., 28:1429 (1936)
(10) Tanaba, H.; Nakagowa, S.; Sata, G.T.; "Effects of Cooling Water Temperature in Particulate Emission from a Small High Speed DI Diesel Engine, SAE Paper 910740.
(11) Alexander, M.V., SAE Paper 880266, "A Modern Approach to Evaluation of Ethylene Glycol Based Coolants," March 1988.

ACKNOWLEDGEMENTS

The authors thank the Cummins Engine Company, particularly the Cummins Technical Center in Columbus, Indiana and Engineering Test Services in Charleston, South Carolina for providing the facilities and equipment used in this program. They also thank ARCO Chemical Company for supplying the propylene glycol prototype coolant and for funding the test program

EXHIBIT 7

Automotive News
Oct. 1, 2007

U.S. agency helps coolant company fight fakes in China

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SHANGHAI — In early 2005, Danielle Zhang, executive director of Shanghai Evans Auto Coolant Sales Co., found shops in China selling coolant very similar to Evans' product.

Zhang wrote to the local governments but got no reply. In China, local governments tolerate fakes because the companies making them create jobs and pay taxes.

But eventually Zhang got help from the government — the U.S. government, that is.

The U.S. Commercial Service stepped in to fight China's bureaucracy. By the end of 2005, the fake product was no longer being sold.

"If we had not had the Commercial Service's help, we would never have been able to get anything accomplished," says Zhang.

The problem is far from solved. Evans regularly finds new copies of its coolant. But Evans' experience offers hope to small companies trying to do business in China. With the right approach, victories are possible.

Early patent helped

Evans Cooling Systems Inc., of Sharon, Conn., produces a patented, nonwater-based engine coolant. The company has around 100 employees, split between the United States and China.

In 2002, Evans sent Zhang, a U.S. citizen born in China, here to set up a sales office. Although the coolant costs up to six times more than some other coolants, Evans figured its product would find a market in China because it reduces emissions and improves fuel efficiency. The coolant is sold in about 600 aftermarket retail shops.

Evans had an important head start when it went after the fake coolant. The company had filed a patent in China on its coolant in the early 1990s, though it wasn't selling in China at that time.

Still, Zhang received no answer from the local governments in Guangzhou and Nanjing when she wrote letters complaining about the fake products. A letter from the Commercial Service produced results, though.

The Commercial Service, part of the Department of Commerce, helps U.S. companies sell goods in China. As part of that mission, it fights counterfeiting.

Zhang: Sought agency's help

Chambers: Got locals' attention

"When the U.S. government got involved, it raised their attention level," says Kevin Chambers, a Commercial Service officer in Shanghai.

The Commercial Service also gave Evans a list of local lawyers with relevant experience and contacted the local governments until the problem was resolved.

Fakes keep coming

Unfortunately, Evans' problem with fakes in China didn't end there. Almost monthly, the company finds a new shop selling fake coolant. So far it has found more than a dozen shops, says Zhang.

"We spend a lot of time and energy trying to follow copies," she says.

But now that Evans has a personal connection with many local governments, it no longer needs to work with the Commercial Service to get action.

Simply notifying the local government that a fake product is being sold isn't enough, says Zhang.

Evans provides the exact location of the shop.

"If the local government thinks it's hard, they won't work with you," she says.

Zhang has a personal commitment to Evans' products. She came to the United States from China in 1985 to attend high school. Evans co-founder Tom Light and his wife were her host family.

After Zhang graduated from Goucher College in Baltimore, she went to work for Grey Advertising. "I always dreamed of working for Evans," she says.

In 2002, when Evans decided to export its product to China, that dream came true.

Zhang has turned the problem of fakes into a business opportunity.

Says Zhang: "We write a letter to the shops selling the fake product and tell them about Evans coolant. Some of them start selling our product instead." AN

XI. RELATED PROCEEDINGS APPENDIX

The Board of Patent Appeals and Interferences issued a decision on May 30, 2003 regarding the parent application, Serial No. 08/991,155 filed on December 16, 1997. A copy of that decision is attached.

62614

The opinion in support of the decision being entered today was ***not*** written for publication and is ***not*** binding precedent of the Board.

Paper No. 12

UNITED STATES PATENT AND TRADEMARK OFFICE

MAILED

MAY 30 2003

PAT. & T.M. OFFICE
BOARD OF PATENT APPEALS
AND INTERFERENCES

BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

Ex parte JOHN W. EVANS

DOCKETED

JUN 10 2003

BY: D. G.
Due 7/30/03

Appeal No. 2001-0741
Application No. 08/991,155

ON BRIEF

Before WILLIAM F. SMITH, DELMENDO and POTEATE, ***Administrative Patent Judges.***

POTEATE, ***Administrative Patent Judge.***

DECISION ON APPEAL

This is an appeal under 35 U.S.C. § 134 from the final rejection of claims 1-8, which are all of the claims pending in the application.

Claim 1 is representative of the subject matter on appeal and is reproduced below:

1. A method of cooling a heat exchange system which comprises circulating a composition in said system, said composition comprising at least about 94.5 weight percent non-buffered propylene glycol, and about 0.05 to about 5.0 weight percent of at least one propylene glycol soluble additive selected from the group consisting of a molybdate salt, a nitrate compound and an azole compound, the composition comprising less than about 0.5 weight percent water.

The references relied upon by the examiner are:

Evans	5,031,579	July 16, 1991
Mascioli et al. (Mascioli)	5,240,631	Aug. 31, 1993
Uekusa et al. (Uekusa)	5,387,360	Feb. 7, 1995
Greaney	5,422,026	June 6, 1995
Reny et al. (Reny) (PCT)	WO 89/09806	Oct. 19, 1989

Coughenour et al. (Coughenour), "Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines" ***Chemical Abstracts***, 120:195478 (1993).

Dingley, R.G., "Aqueous and Non-Aqueous Engine Coolants Based On Propylene Glycol," ***Chemical Abstracts***, 116:865516 (1991).

GROUNDS OF REJECTION [1]

1. Claims 1-8 stand rejected under 35 U.S.C. § 103 as unpatentable over Coughenour in view of Mascioli or Greaney or Uekusa.

2. Claims 1-8 stand rejected under 35 U.S.C. § 103 as unpatentable over Dingley in view of Mascioli or Greaney or Uekusa.

3. Claims 1-8 stand rejected under 35 U.S.C. § 103 as unpatentable over Evans in view of Mascioli or Greaney or Uekusa.

4. Claims 1-8 stand rejected under 35 U.S.C. § 103 as unpatentable over Reny.

We affirm as to the first two grounds of rejection and this constitutes the disposition of the appeal. Consequently, we do not reach grounds of rejection 3 and 4.

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[1] The rejection of claims 1 and 5 under 35 U.S.C. § 112, first paragraph, has been withdrawn. Examiner's Answer, Paper No. 11, mailed August 2, 2000, page 2, paragraph (3).

BACKGROUND

The invention relates to a method of cooling a heat exchange system by circulating a composition comprising a non-buffered propylene glycol based coolant that is essentially non-aqueous, i.e., the composition contains less than about 0.5 weight percent water. See Appeal Brief, Paper No. 10, received April 27, 2000, page 4. According to appellant, he has discovered that the elimination of smaller amounts of water from a propylene glycol-based coolant composition results in significant advantages which include improved heat transfer, less corrosion, lower operating pressure, a long shelf life and lower toxicity. ***Id.***, pages 4-6.

DISCUSSION

In making a patentability determination, analysis must begin with the question, "***what*** is the invention ***claimed***?" since "[c]laim interpretation . . . will normally control the remainder of the decisional process." ***Panduit Corp. v. Dennison Mfg. Co.***, 810 F.2d 1561, 1567-68, 1 USPQ2d 1593, 1597 (Fed. Cir.), ***cert. denied***, 481 U.S. 1052 (1987). In the present case, the invention

claimed is a method of cooling a heat exchange system which comprises circulating a composition in the system. Claim 1. The claimed invention further requires that the composition comprise at least about 94.5 weight percent non-buffered propylene glycol and about .05 to about 5 weight percent of at least one propylene glycol soluble additive. ***Id.*** As pointed out by the examiner, the claim 1 requirement that the composition comprise less than about 0.5 percent water reads on compositions containing *no water*. Examiner's Answer, sentence bridging pages 8 and 9.

Both Coughenour and Dingley disclose the use of non-aqueous propylene glycol as engine coolants, i.e., the coolants do not contain water. See Examiner's Answer, page 5. Appellant distinguishes these teachings from the claimed invention by noting that the references do "not describe any specific levels of water, non-buffering, or any propylene glycol soluble additives." Appeal Brief, pages 11-12.

The examiner notes that neither Coughenour nor Dingley discloses *the inclusion of* buffers. Examiner's Answer, page 9. The examiner concedes that neither Coughenour nor Dingley discloses the use of a molybdate salt, a nitrate compound or an azole compound (corrosion inhibitors). ***Id.***, page 6. However,

the examiner notes that each of Mascioli, Greaney and Uekusa discloses propylene glycol antifreeze coolant compositions containing one or more of these additives. The examiner concludes that it would have been obvious to one of ordinary skill in the art to add one of these additives to the compositions of Coughenour or Dingley since these compositions would benefit from the corrosion inhibition of the additives as taught by the secondary references. ***See id.***

Appellant does not appear to dispute the examiner's findings with respect to Coughenour, Dingley and the secondary references, or the examiner's proposed motivation for combining the references. Accordingly, we conclude that the examiner has established a ***prima facie*** case of obviousness with respect to claims 1-8.

A ***prima facie*** case of obviousness may be overcome through a showing of unexpected results, i.e., that the claimed invention exhibits a superior property or advantage that would be considered surprising or unexpected by one of ordinary skill in the art. ***In re Geisler***, 116 F.3d 1465, 1469, 43 USPQ2d 1362, 1365 (Fed. Cir. 1997). In support of patentability of the claimed invention, appellant relies on previously filed

Declarations under 37 CFR § 1.132, copies of which are submitted as attachments to appellant's Brief. See Appeal Brief, Appendices 2 and 3. It is appellant's position that "the December 3, 1996 Declaration demonstrates that there are unusual and unexpected results when the percentage of water in a propylene glycol coolant formulation is decreased from 1.0% to 0.5%." Appeal Brief, page 9 (discussing Appeal Brief, Appendix 2). However, we are in agreement with the examiner that the data presented in this Declaration does not appear to be unusual or unexpected since it was known in the art that compositions containing 100% propylene glycol, when employed as coolants, do not exhibit any observed "knock." Examiner's Answer, page 8. As noted above, the claims read on compositions which do not contain any water. ***See supra***, page 4. Accordingly, we conclude that the Declarations under 37 CFR § 1.132 do not overcome the examiner's ***prima facie*** showing of obviousness.[2] The rejection of claims 1-8 as unpatentable over Coughenour or Dingley in view of Mascioli, Greaney or Uekusa is affirmed.

---

[2] The second Declaration, found in Appendix 3, relates solely to the Evans patent and is not relevant to Dingley, Coughenour, or any of the secondary references.

Having concluded that the claims are unpatentable for the reasons noted above, we need not reach the issues of whether the claims are unpatentable over Reny, or over Evans in view of Mascioli, Greaney or Uekusa. In any event, we note that these issues are not ripe for consideration since neither the appellant nor the examiner has considered all relevant evidence for the reasons discussed below.

COMMENTS ON EXAMINER'S REJECTION

In rejecting the claims, the examiner relies on the Chemical Abstracts of the Coughenour and Dingley articles. Both of the Chemical Abstracts have copyright dates of 1996, which is after the May 24, 1995 filing date of the parent application (the present application being indicated as a continuation of the parent). On Form PTO-892, the examiner indicates the dates of the abstracts as being the publication dates for the underlying full text articles. We have compared the Chemical Abstracts with the abstracts which appear in the full text articles and note that the language contained in the Chemical Abstracts is identical to that which appears in the full text article abstracts.

The examiner apparently obtained the full text Coughenour and Dingley articles in July, 2000, but does not rely on the full text articles, nor are they even mentioned in the Examiner's Answer or the Appeal Brief.[3] Our decision is, therefore, based solely on the arguments of the examiner and appellant with respect to the Chemical Abstracts. We have, however, reviewed the full text articles and note that the examiner's position regarding the motivation to combine Coughenour and Dingley with the secondary references is further supported by the full text Dingley and Coughenour articles which discuss the importance of low corrosivity in engine coolant compositions. ***See, e.g.***, Dingley, page 1, paragraph 2 and Coughenour, page 90, column 1, first full paragraph.

In the event that appellant elects to continue prosecution, the Reny and Evans disclosures should be considered in light of the full text Coughenour article. Specifically, in the full text article, Coughenour discloses testing of coolants comprising 100% propylene glycol, a 50/50 propylene glycol and water composition, and 100% water. Coughenour concludes that

[3]It is unclear whether appellant has reviewed the full text articles. Copies of these articles are being provided as attachments to this Decision.

"[n]on-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression." Page 96, first column. The examiner and appellant should consider whether one of ordinary skill in the art would have been motivated to exclude water from the compositions of Reny or Evans in view of Coughenour's teaching.

TIME PERIOD FOR RESPONSE

No time period for taking any subsequent action in connection with this appeal may be extended under 37 CFR § 1.136(a).

AFFIRMED

William F. Smith
WILLIAM F. SMITH
Administrative Patent Judge

Romulo H. Delmendo
ROMULO H. DELMENDO
Administrative Patent Judge

BOARD OF PATENT APPEALS AND INTERFERENCES

Linda R. Poteate
LINDA R. POTEATE
Administrative Patent Judge

LRP:psb

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930584

Evaluation of Non-Aqueous Propylene Glycol as an Engine Coolant for Heavy Duty Diesel Engines

G. E. Coughenour
ARCO Chemical Co.

L. K. Hwang
Cummins Engine Co.

ABSTRACT

Five different engine tests utilizing non-aqueous propylene glycol as the engine coolant were run to examine various aspects of durability and engine performance. This paper reports the results of these engine and bench tests designed to quantify the effects on performance and engine durability. Comparisons are made to baseline engine tests using 50 % aqueous ethylene glycol coolant. Also reported are the data necessary to determine the effects on the size and design of related heat exchangers.

Based on these test results, some of the presumed advantages and disadvantages of the use of non-aqueous propylene glycol engine coolants (1)* have been quantified. This work is useful as a basis for further work using total-vehicle systems taking advantage of this innovative technology.

INTRODUCTION

An internal combustion engine must have an effective means of rejecting the energy liberated that can not be recovered as work. This is the function of the cooling system, the main component being the coolant fluid. The choice of this coolant directly affects the durability and performance of the engine.

Glycol/water mixtures are generally used for this service. They work rather well for heat rejection, but their limitations make a more advanced coolant desirable. Water is one of the best convective heat transfer media available, but because it is also a great solvent its presence leads to corrosion issues. This can be managed with inhibitor technology, but this is cumbersome and expensive. In heavy duty applications where long life is an important design criterion, cast aluminum is not used in contact with coolant because adequate component life can not be achieved. If water were not used, lower cost aluminum castings could be used without sacrificing engine life expectancy.

* Numbers in parentheses designate references at end of paper.

Another serious problem results from the low boiling point of water. Localized boiling will occur inside the cooling channel if the local temperature exceeds the coolant boiling point. Although boiling is the most effective means of enhancing heat transfer, problems arise if the vapor is not removed as fast as it is generated. If the vapor is not swept away by coolant flow, or if the heat flux from the metal is too high, the nucleate boiling phase will change to a film boiling phase, forming a layer of vapor on the metal surface. This vapor blankets heat transfer and the burn-out point is reached. This condition generally leads to engine failure. Pressurizing the cooling system raises the boiling temperature, but adversely effects the safety and durability of the cooling system. Burns from opening the cooling system of an overheated engine, or just one that has recently been shut down, are a serious hazard.

When a heavily loaded engine is stopped, the coolant circulation stops resulting in subsequently low heat transfer rates. If the coolant has a low boiling point, vapor blanketing can occur at hot spots. If the engine is restarted under this condition, scuffing can occur because of inadequate cooling.

The vapor bubbles formed from low boiling point coolants are also known to result in cavitation damage to cylinder liners and coolant pumps. This problem can be reduced with supplemental coolant additives, but it is costly and tedious to assure that balanced chemistry is maintained.

A water-free, or non-aqueous, system, is thus desirable.(2) One such system has been patented by Evans Cooling, Sharon, Connecticut. (3)(4) The system uses a neat or undiluted propylene glycol engine coolant.(5) This evaluation of the -694 patent, as adapted to a Cummins diesel (slow-flow with condenser), verifies concern for the lower convective heat transfer characteristics of the non-aqueous coolant and resultant higher metal temperatures as well as concerns regarding viscosity differences, of the coolants, and the possible need for increases in heat exchanger frontal area. A subsequent Evans' patent,(6) patents pending, and application experience address and correct these deficiencies. The

improvements warrant consideration for any future testing or application of the cooling technology.

Propylene glycol is attractive as a heat transfer fluid because it has a low freezing point (-70°F), high boiling point (369°F), low corrosivity, low toxicity, is biodegradable, is readily available in adequate quantities, and is reasonably priced.(7) Compared to a glycol/water solution, neat glycol has some drawbacks as heat transfer fluids that require study to judge the merit of such an innovative cooling system.

Specifically, the convective heat transfer coefficient predicted for neat glycol is much lower than that of a glycol/water solution.(8) Figure 1 shows a plot of the Sieder & Tate relationship (9) for a series of fluids ranging from water to SAE 15W-40 lubricating oil. As can be seen, adding glycol to water reduces this coefficient by more than half. Neat propylene glycol is nearly the same as diesel fuel. The lubricating oil is the poorest of these fluids. The viscosity of propylene glycol also raises some fluid flow concerns in areas of high pressure drop such as the heater circuit of an on-highway truck.

Figure 2 reflects these heat transfer differences for ethylene glycol/water, propylene glycol/water and non-aqueous propylene glycol coolant on the effectiveness of the radiator. On average the undiluted glycol reduces the effectiveness by 20%.

A conclusion regarding the value of a non-aqueous glycol coolant can not be reached without some empirical study of all these effects combined. Such an evaluation program was conceived to accomplish that.

COOLANT EVALUATION PROGRAM

An extensive program was executed to gauge the effects of using neat propylene glycol coolants on the performance of a heavy duty engine. For the purpose of this study, the cooling system flow pattern was not altered, i.e. the coolant returning from the radiator entered the coolant pump, oil cooler, the aftercooler, the lower section of the cylinder cooling jackets, cylinder head and exited from the upper chamber of the water header to the radiator. There were some alterations employed to isolate specific effects that will be described as those analyses are presented.

The work was done with a Cummins L-10 six cylinder turbocharged diesel engine of an experimental 1991 configuration.

After chassis dynamometer runs confirmed that neat propylene glycol coolant would function adequately in this engine, a test cell dynamometer program commenced which evaluated the engine performance and heat balance over a matrix of operating conditions. A 500 hour durability test, emissions testing, and a cold start white smoke test followed. The effects of the neat propylene glycol coolant on commonly used elastomers were evaluated in parallel laboratory work.

CHASSIS DYNAMOMETER RESULTS - The initial testing of propylene glycol as an engine coolant was done by the application group of the Cummins Engine Company. An L-10 engine equipped with a low flow cooling system (OAC) was installed in a truck to be run in a wind tunnel on a chassis dynamometer. A four-by-two test matrix was run. Water, a 50/50 mixture of ethylene glycol and water, a 50/50 propylene glycol and water, and 100% propylene glycol were used as coolants while the engine was run at two different conditions: 1800 RPM / 100 lb/hr fuel rate and 1300 RPM / 78 lb/hr fuel rate. The results are shown in Tables 1 and 2, and Figures 3 and 4. It is clear that while there is no significant difference between the two aqueous solutions, the 100% PG coolant requires lower ambient (air side) temperature to achieve the target top tank temperature. Oil temperature and the cylinder liner temperatures are higher, indicating the expected poorer heat transfer in the convective regime.

Although non-aqueous propylene glycol has some detriments when used in a system configured for an aqueous mixture, it did work well enough to warrant further investigation in the controlled environment of the dynamometer cell.

TESTING PROGRAM - A 1991 L-10 prototype engine was used for this program. The engine configuration was:

Rating:	330 HP @ 1800 RPM
Torque Peak:	1150 ft-lbs @ 1200 RPM
Fuel System:	PTD fixed timing
Camshaft:	Rate control cam P/N 3053006
Compression Ratio:	16
Turbocharger:	Holset H2D 9351/1903

The engine was assembled at the Cummins Technical Center and shipped to Engineering Test Service in Charleston, South Carolina for installation in a dynamometer cell.

Computerized data gathering was used with extensive instrumentation to measure performance, temperatures, and pressures. The engine operating parameters collected during the test include:

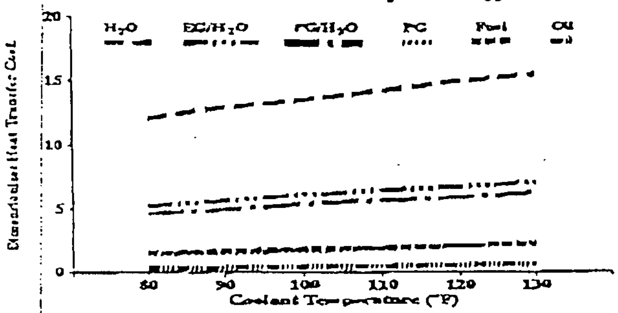
Engine Parameters:	Engine Speed, Engine Torque, Fuel Rate, Smoke (BSU), Air Flow
Temperatures:	Coolant Inlet, Coolant Outlet, Oil Pan, Fuel Inlet, Intake Manifold, Crossover, Exhaust, Turbine Inlet, Stack, Cell (Ambient)
Pressures:	Inlet Restriction, Intake Manifold, Turbine Inlet, Crossover, Stack, Blowby, Coolant Pump Discharge, Oil Rifle, Fuel Rail, Coolant Pressure, and Barometric Pressure (Cell)

The following special instrumentation was used:

CYLINDER HEAD TEMPERATURE MEASUREMENT - The exhaust and intake valve bridges of cylinders #1 and #6 were fitted with thermocouples as shown in Figure 5. Grooves were machined 0.070 inch deep on the firing deck surface to get temperature measurement as close to the cylinder

Figure 1

Working Medium Property Impact on Convective Heat Transfer Coefficient



Note: Sieder & Tate Correlation

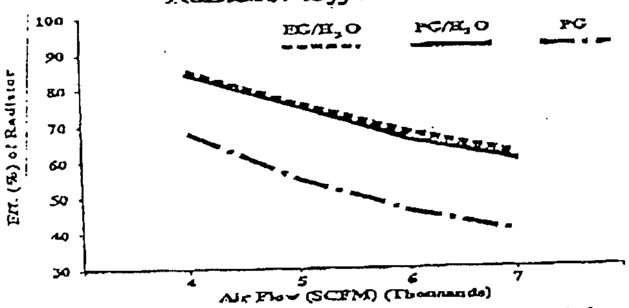
Table 2

Chassis Dynamometer Test Results

1300 RPM	Coolant: Water	EG/Water	PG/Water	PG
Ambient Temp(°F)	110	106	106	88
Top Tank ΔTemp (°F)	90	95	94	119
Bottom Tank ΔTemp (°F)	40	39	40	39
Avg. Cylinder Liner (°F)	316	343	349	406
Oil Temperature (°F)	230	243	245	289
Fuel Rate (lb/hr)	78.1	79.2	78.1	76.3

Figure 2

Coolant Impact on Radiator Effectiveness



Note: Coolant Flow Rate 100 GPM, Coolant In 210 °F, Air In 106 °F

Figure 3

Chassis Dynamometer Test Results at 1800 RPM

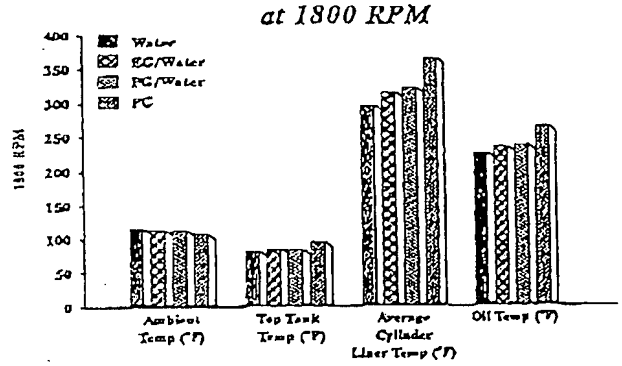


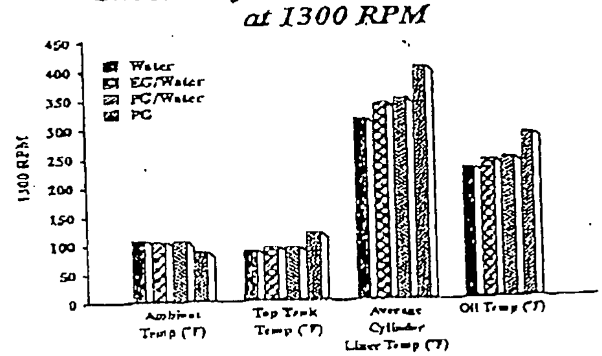
Table 1

Chassis Dynamometer Test Results

1800 RPM	Coolant: Water	EG/Water	PG/Water	PG
Ambient Temp(°F)	117	114	114	107
Top Tank ΔTemp (°F)	82	85	84	95
Bottom Tank ΔTemp (°F)	41	40	40	43
Avg. Cylinder Liner (°F)	298	316	322	366
Oil Temperature (°F)	226	234	237	265
Fuel Rate (lb/hr)	101.3	98.1	100.3	97.0

Figure 4

Chassis Dynamometer Test Results at 1300 RPM



head surface as possible. After the thermocouples were laid in the grooves, the cylinder head was resurfaced. These two pairs of thermocouples allowed the measurement of the greatest temperature differential across the cylinder head.

CYLINDER LINER TEMPERATURE MEASUREMENT - The #3 cylinder liner was machined on the outside diameter and twelve thermocouples installed as indicated in Figure 6. Four were placed at ninety degree intervals around the circumference at the top ring reversal height, the bottom ring reversal, and at an intermediate point.

MEASUREMENT OF HEAT REJECTION - The total coolant heat rejection and the oil cooler heat rejection were measured using venturi tube flow meters and precision thermocouples.

To isolate the coolant as the sole test variable, the oil cooler was separated from the engine cooling loop and provided with an independent temperature control. The oil temperature was maintained constant at 230°F. Similarly, the fuel temperature was maintained at 100°F.

In order to minimize the coolant pump inlet pressure, the coolant makeup tank was lowered as much as possible while preventing coolant from flushing back. A condenser was fitted to the tank vent to recover any vapor that might occur in the system if there were boiling.

TEST MATRIX - A five by four by two test matrix was run to gather the above operating data over a range of engine operating speeds from 800 RPM to 1800 RPM, engine loads at 50% and 100%, and coolant variations beginning with an aqueous ethylene glycol baseline at 180°F coolant outlet temperature, then changing to non-aqueous propylene glycol with a coolant outlet temperature at 180°F, 200°F, 220°F and 240°F. Energy balances were done for each coolant variable. Heat exchanger sizing calculations were done for each as well.

DURABILITY TEST - The instrumented engine was run on the dynamometer at rated conditions for 500 hours. In addition to the data prescribed in the test above, oil degradation, oil soot loading, oil consumption, ring wear, cylinder liner wear, piston land carbon deposit, elastomer compatibility, and coolant degradation were monitored either by sampling during the test or inspection upon disassembly at the test completion.

EMISSIONS TESTING - Steady state emissions testing was done at a coolant outlet temperature of 230°F for propylene glycol and compared to baseline run on ethylene glycol water at 180°F. Prior work suggested that higher temperature reduced particulate emissions.(10)

COLD START WHITE SMOKE TEST - This was done with the engine operating on propylene glycol and ethylene glycol/water for direct comparison. The engine was soaked overnight at 32°F before the coldstart test was performed. Hydrocarbon emissions were tracked during the test.

BENCH TESTING OF ELASTOMER COMPATIBILITY - The various non-metallic engine materials were tested for compatibility with ethylene glycol/water, propylene glycol/water, and propylene glycol on a rig test in a 257°F temperature bath. Nitrile rubber, silicone rubber, ethylene propylene rubber, and Viton were checked for compatibility by measuring tensile strength, elongation, compression set, swell, and Shore hardness changes at one week and three weeks of immersion in the coolants. (11)

1000 HOUR THERMAL CYCLE TEST - The engine was run through a 1000 hour operating cycle on a dynamometer. This test has been developed by Cummins as an accelerated method to check component life in new designs. The engine is over-stressed relative to its rating in operating speed, fuel-rate, and operating temperature to reveal weaknesses.

DISCUSSION OF TEST RESULTS - Generally the engine ran well on the non-aqueous propylene glycol coolant. There were several observations consistent with the poorer heat transfer characteristics of undiluted glycol and the higher coolant temperatures used in the test.

As the coolant temperature was increased, the efficiency of the engine was unchanged. The heat rejection via the coolant was reduced significantly. About a quarter of that decrease appears attributable to the lower heat transfer coefficient of undiluted glycol and the balance due to reducing the temperature differential between the combustion chamber and the coolant. Since the engine was not modified to capture this reduction in energy loss, it was just transferred to the exhaust and the oil cooler. (Figure 7)

Engine metal temperatures changed as a result of the tested coolant changes. At the rated engine condition, the change in coolant from aqueous ethylene glycol to non-aqueous propylene glycol resulted in cylinder liner temperature increases of 14°F for the highest liner temperatures and 21°F for the lowest. Thereafter, increasing the coolant temperature increased these further at a rate of 0.5 to 0.7°F per 1°F coolant temperature change. (Figure 8)

At the torque peak, the coolant change resulted in liner temperature increases of 25°F for the maximum temperatures and 20°F for the minimum. Coolant temperature increases resulted in liner temperature increases at the same rate as at the rated condition. (Figure 9)

The cylinder head temperatures increase also. At the rated condition, changing the coolant to non-aqueous increases the intake valve bridge temperature by 15°F and the exhaust valve bridge by 30°F. Coolant temperature increases are again reflected at a reduced rate, 0.6°F per 1°F coolant temperature change. (Figure 10)

At the torque peak, changing to non-aqueous coolant increases the intake valve bridge by 18°F and the exhaust by 45°F. The intake side increases 0.5°F per 1°F in coolant temperature change, but the exhaust side increased at 0.75°F per 1°F coolant change. Clearly the reduction in convective heat transfer resulting from removing the water from the coolant is more greatly reflected in the cylinder head with its high heat flux. (Figure 11)

RADIATOR AND OIL COOLER ANALYSIS - The total engine heat rejection via the radiator and oil cooler was plotted against the coolant variables in Figures 12. As noted previously, changing from

Figure 5

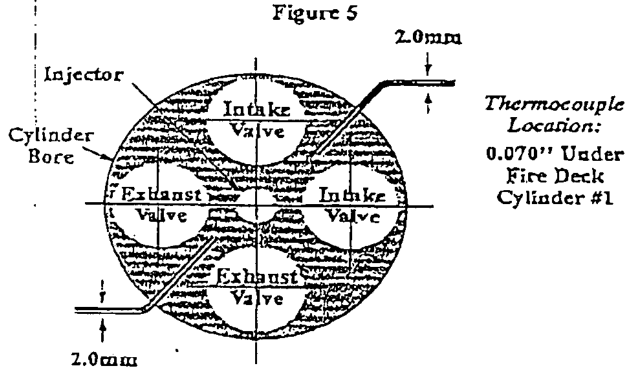


Figure 8
Liner Temperature at Rated Condition

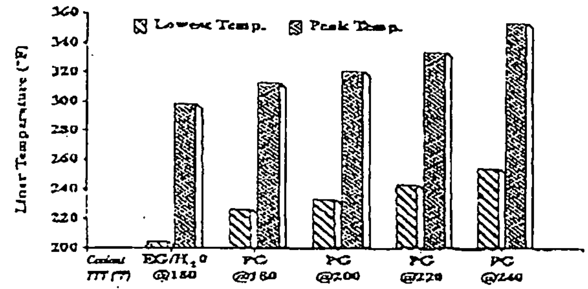


Figure 6
L10 Cylinder Liner Thermocouple Locations
(millimeters)

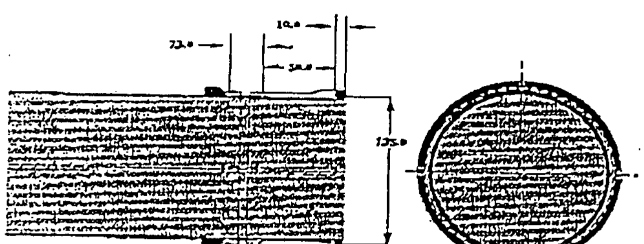


Figure 9
Liner Temperature at Torque Peak

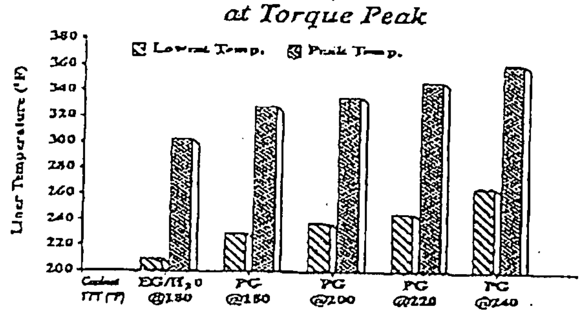


Figure 7
Engine Heat Balance @ Rated Conditions for Tested Coolants & Temperatures

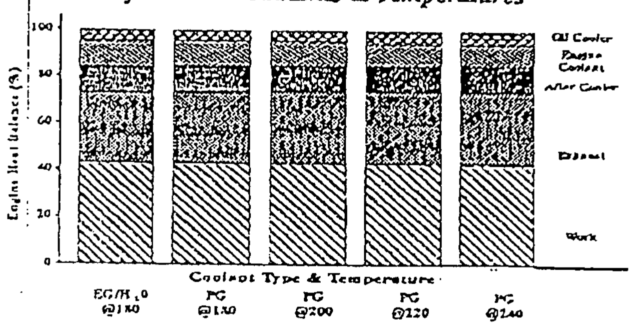
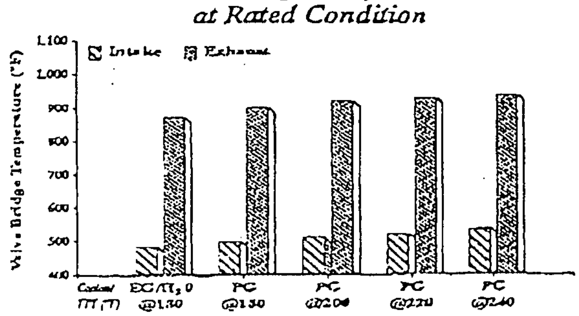


Figure 10
Valve Bridge Temperature at Rated Condition



aqueous ethylene glycol to non-aqueous propylene glycol reduces the heat transferred through the coolant and increases the heat transferred through the engine oil . The data collected indicates that the total heat rejection increased, but this appears to be an artifice of the test since there is no theoretical reason why this should happen. As the coolant temperature is raised, the radiator heat load is reduced and the oil cooler load increased, but the total load decreases. Furthermore, as the coolant temperature is increased the area required for heat transfer of course decreases.

All of this information was evaluated by the McCord Heat Transfer Corporation who sized the radiator and air-cooled oil cooler for each coolant variable point. An air-cooled oil cooler was specified because an oil temperature of 230°F was needed to continue the use of conventional engine oils. This could not be done with coolant temperatures above 200°F. As can be seen in Figure 13, the higher temperatures permit the use of a radiator and oil cooler that are approximately equal size and have less than 75% of the required frontal area as needed for the radiator in the ethylene glycol/water base case. However, simply changing from ethylene glycol/water to non-aqueous propylene glycol at normal operating temperature increases the radiator size required by almost 15%.

EFFECT ON COLD START EMISSIONS - A Cummins L-10 engine with electronically controlled fuel injection was soaked in a cold test cell at 32°F. The test protocol is to start the engine and let it idle while measuring its hydrocarbon emissions as a function of time. Figure 14 shows the results of the test run on EG/water and on non-aqueous PG. In the PG case, the coolant and oil temperatures both increased more rapidly, but there was no apparent reduction in the hydrocarbon emissions. The electronic control does such a good job that the faster warmup has little effect on emissions from cold starting.

EFFECT ON STEADY STATE ENGINE EMISSIONS - To determine if non-aqueous propylene glycol coolant would have any effect on engine emissions, a steady state simulation (Figure 15) of the EPA Transient Emission cycle was run on EG/water at 180°F and PG at 240°F. The engine was modified to isolate the oil cooler and the intake manifold temperature was held constant at 125° F. Figure 16 summarizes the results. Although the hydrocarbon emissions seem to be higher with PG the difference is within the measurement error at these low levels.

EFFECT OF NON-AQUEOUS PROPYLENE GLYCOL ON ENGINE ELASTOMERS - The results of the parallel tests run with EG/water, PG/water, and non-aqueous PG on typical elastomers used were (Table 3):

1. The performance of silicone, Viton, nitrile, and EPDM rubbers were not affected by substituting PG for EG in a 50% aqueous solution with Fleetguard DCA4 additive added.
2. Nitrile rubber swelled about 40% in non-aqueous PG. Its compression set was not significantly changed. The high swell may be detrimental to elastomer parts such as the coolant pump bellows seal and some crevice seals.
3. EPDM performed well in all PG solutions.
4. Viton displayed the same surface cracking in PG/water and non-aqueous PG as it does in EG/water.

500 HOUR ENDURANCE TEST - The L-10 engine was set up to operate at 330 BHP and 220°F coolant outlet temperature. Cummins Premium Blue oil was used and oil temperature held at 230°F. Oil samples were drawn every 50 hours for analysis. After 250 hours there appeared to be no apparent deterioration, so the coolant outlet temperature was increased to 240°F to accelerate the test.

The fuel rate and BSFC were both reasonably stable throughout the test and the oil pressure held steady at 35 psi. Exhaust stack temperature increased slightly with the coolant temperature. Oil consumption was very low. There was no increase in oil deterioration when the oil analyses were compared to reference analyses of oil samples taken at similar conditions except with standard coolant conditions. This is not surprising since the oil sump was held at normal temperature, but it does indicate that no surfaces became hot enough to "crack" the oil when using propylene glycol coolant.

Upon disassembly, a few parts indicated the need for changes for continued operation at higher coolant temperatures. Some of the gasket and seal materials were hardened, indicating the need of more robust materials. The pistons and piston rings showed some abnormally high wear, indicating that a different type should be used at these higher temperatures. There was some polishing of the inside of the cylinder liners, indicating marginal cooling at some spots. In a favorable sense, the coolant system passages and other components including the coolant pump were in excellent condition. There was no evidence of pitting on the cylinder liners or the adjacent engine block walls. The cylinder head passages were very clean.

1000 HOUR THERMAL CYCLE TEST - The test cycle was taken from Cummins engine design experience, but modified to incorporate the coolant change and higher coolant outlet temperature. Figure 17 depicts the cycle. It begins with 5 minutes of 10% over-fueling at rated speed and engine coolant outlet temperature of 250°F. The next stage is 2 minutes of 10% over-speed at no load and the coolant temperature at 235°F. The last phase is 2 minutes of idling at 235°F coolant temperature. The cyclic thermal stressing of the engine on both load and speed is intended to reveal weaknesses.

During the test there was one failure that was attributable to the higher operating temperature. Four of the six aluminum pistons cracked at the pin bore because of the higher combustion pressure and higher operating temperature after 496.5 hours. These pistons were replaced with new articulated pistons having steel caps and new rings, then the test was resumed. The last 500 hours were completed without incident.

Upon disassembly the coolant passages were in excellent condition. There was no evidence of pitting on the cylinder liners or the block walls. This is doubly significant because this particular engine block

Figure 11

Valve Bridge Temperature at Torque Peak

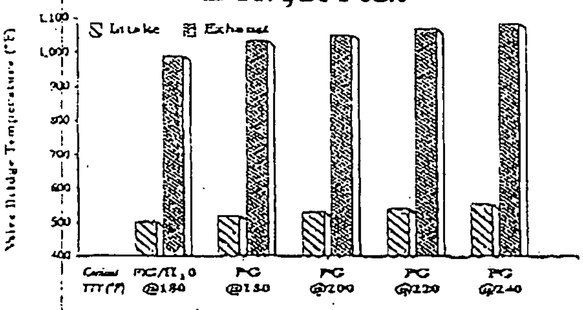


Figure 14

Coolant Impact on L10 Engine Cold Start

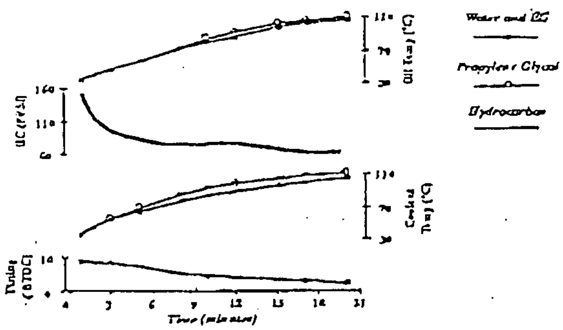


Figure 12

Heat Rejections with Various Coolants & Temperatures at Rated Condition

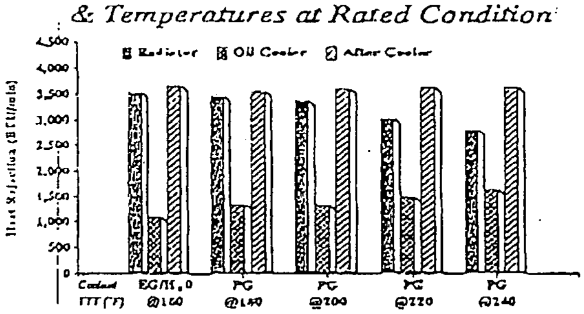


Figure 15

8-Mode Transient Cycle Simulation

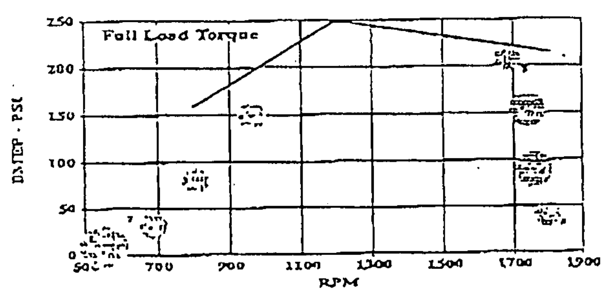


Figure 13

Radiator and Oil Cooler Sizes

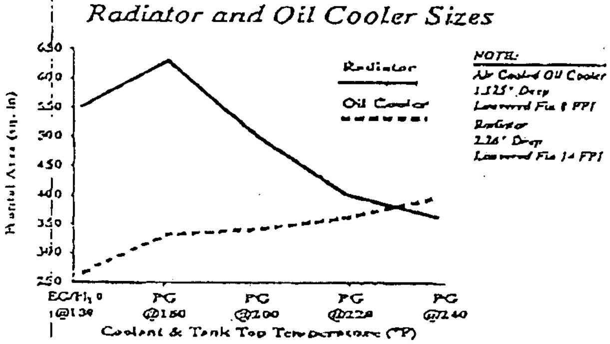
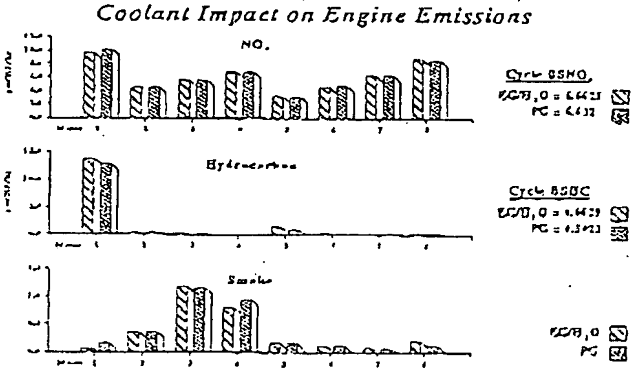


Figure 16

Coolant Impact on Engine Emissions



was a prototype L-10 configuration that had restricted coolant flow passages around the liner that promote liner pitting. In similar tests with conventional EG/water coolants, pitting was observed. The production L-10 configuration corrected this propensity. Although the test was not designed to evaluate the cavitation characteristics of PG coolant, it did bear witness to this quality of propylene glycol.

There was no indication of deterioration of the articulated pistons used in the last 500 hours, nor any indication of contact between the liner walls and the piston skirts or rims. Carbon and varnish buildup was normal. The connecting rod bearings had fatigue failure attributed to the high output of the engine for this test. Some of the gaskets and O-rings were hard and brittle after operating at higher temperatures. Oil analysis did not indicate any abnormal wear and coolant analysis showed no deterioration. There was some water found in the coolant samples which was traced to contamination of the makeup glycol.

SUMMARY AND CONCLUSIONS - Use of non-aqueous propylene glycol as the coolant in a production heavy duty diesel engine was thoroughly studied. In general this conversion is possible with some tradeoffs.

Non-aqueous propylene glycol demonstrates extremely good engine cooling system corrosion protection and cylinder liner cavitation suppression. It also provides a greater margin of boil-over and vapor blanketing protection at a lower cooling system operating pressure. Cavitation damage in the coolant pump should be eliminated. Cooling system maintenance and chemical addition should be greatly simplified.

Non-aqueous propylene glycol does exhibit the reduced convective heat transfer predicted from its physical properties. At the same coolant temperature, theoretically this results in a need for larger radiator and oil cooler (if coolant used for oil cooling) than a glycol/water mixture requires. In actual practice, a larger radiator may be installed with glycol/water for overheating protection. In any case, heat exchanger sizes should be checked before coolant changes are made.

Within the range of temperatures studied, other than the possibility of reducing radiator size, there is no benefit to operating at higher coolant outlet temperatures. Engine efficiency and emissions are not significantly changed. The reduction in heat rejected via the coolant is offset by increased heat rejection via the exhaust and the oil cooler. The exhaust gas energy increase is too small to justify increased energy recover such as turbo-compounding.

Higher operating temperatures appear possible with relatively minor engine changes such as upgraded piston kits, different gasketing and seal materials, and higher performance lubricants. Although metal temperatures were increased in these tests, there was no evidence of increased failure rate in the cylinder head and other major components. This observation must be verified by long term statistical field failure tracking before propylene glycol would become an established coolant.

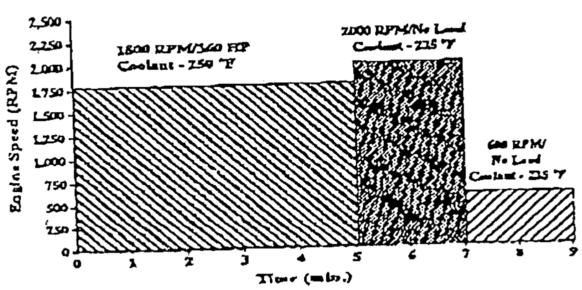
Changing from a glycol/water mixture to non-aqueous glycol requires evaluation of the elastomers used. The higher swell observed with nitrile rubber could be detrimental in some applications. EPDM performance is better without water contact.

In applications where boilover, cooling system corrosion, or coolant pump or cylinder liner cavitation are a significant problem, changing to non-aqueous propylene glycol may be a solution if done with the appropriate evaluation of the overall system. To achieve lower emissions or higher engine efficiency requires taking advantage of non-aqueous propylene glycol's higher operating temperature potential with modified engine designs.

It should also be noted that further developments have been made in this technology since this test program was conducted that address many of the issues identified in this work.

Figure 17

Nonaqueous Propylene Glycol Coolant
1000 Hr Thermal Cycle Test



REFERENCES

(1) Light. J. Thomas, "Hybrid Engine Cooling," A Presentation to the ASTM Committee D-15 on Engine Coolants, St. Louis, Missouri, October 6, 1987.
(2) Dawson, Dan; Flesher, Bob; Joyce, Bill Jr.; Kennedy, Tom; Kirk, Carl; Moffitt, Mike; Rood, George; Sullivan, John; Suski, Vic; Tyink, David; "Tomorrow's Trucks: The Users Perspective-An Update;" SAE Paper 872243: November 1987.
(3) Evans, John W., "Process and Apparatus for Cooling Internal Combustion Engines," United States Patent Number 4,550,694, November 5, 1985.
(4) Evans, John W. and Light, J. Thomas, SAE Paper 861428, "Expanding the Limits on Engines and Vehicles Imposed by Circulating Liquid Engine Cooling Systems," September 1988.
(5) Remy, Greg P.; Titley, Guy L.; "Development of an Anhydrous Coolant for Automotive Applications," SAE Paper 9000432.
(6) Evans, John W., "Cooling System for Internal Combustion Engines," United States Patent Number 5,031,579, July 16, 1991.
(7) Coughenour. Glenn E.; Hercamp, Richard D.; Hudgens, R. Douglas; "Aqueous Propylene Glycol Coolant for Heavy Duty Engines," SAE Paper 900434, March 1990.
(8) Boyle. R.J.; Biddulph, T.; Finlay, I.C ; Marshall, R.A.; "Heat Transfer to Non-Aqueous Engine Coolants," SAE Paper 910304.
(9) Siedy, B.N., and Tate, G.E., "Heat Transfer and Pressure Drop of Liquids in Tubes," Ind. Eng. Chem., 28:1429 (1936)
(10) Tanabe, H.; Nakagowa, S.; Sata, G.T.; "Effects of Cooling Water Temperature in Particulate Emission from a Small High Speed DI Diesel Engine, SAE Paper 910740.
(11) Alexander. M.V., SAE Paper 880266, "A Modern Approach to Evaluation of Ethylene Glycol Based Coolants," March 1988.

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AQUEOUS AND NON-AQUEOUS ENGINE COOLANTS BASED ON PROPYLENE GLYCOL

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1 INTRODUCTION

Engine coolants form a vital function in most internal combustion engines. The reason for this is that only about a third of the energy liberated by burning fuel is used to generate motive power, another is dissipated in the exhaust and the rest heats the metal of the engine. This paper discusses the use of monopropylene glycol (MPG) as the antifreeze component of a modern coolant and briefly summarises the HYBRID™ system in which the entire coolant is MPG.

2 CHARACTERISTICS OF ENGINE COOLANTS

If the heat generated in the metal of the engine were not removed, the engine would finally seize as the lubrication system failed. The main function of the cooling system, therefore, is to transfer heat from the metal of the engine to the radiator so that it can be safely dissipated to the atmosphere. To carry out this function the fluid should have a high specific heat, be liquid over the entire operating range of the engine, have a high boiling point and low freezing point, it should not corrode the metals of the engine, it must be chemically stable, it should not be flammable or toxic and of course it should be readily available and inexpensive.

No single material can satisfy all these demands but fortunately water comes closest with high cooling power and good heat transfer characteristics.

Unfortunately, it also has several deficiences. In particular it freezes at too high a temperature and boils at too low a temperature and in the presence of air, it is highly corrosive to metals.

To overcome the high freezing point, most people know that a glycol is dissolved in the coolant water but in a commercial antifreeze concentrate, there can be up to ten other ingredients which act to prevent corrosion of the metals of the engine and reduce the degradation of the glycol. With the increased performance of modern vehicle engines, manufacturers are developing more stringent requirements for the coolants and furthermore there is increased awareness of the need to use safe, non-toxic products whenever possible in any industrial or consumer environment. For these reasons MPG is being increasingly considered, not only as a viable antifreeze product, but as the preferred product where high performance and safety to the public are concerned.

3 PROPYLENE GLYCOL AS AN ANTIFREEZE

Since the main function of the glycol is to reduce the temperature at which the fluid ceases to function, it is instructive to compare the freeze point of ethylene glycol (EG) and MPG solutions in water at various concentrations. Figure 1 shows the freeze point measured using ASTM D-1177 for volume concentrations of glycols from 0 to 60%. The difference in freeze point measured by this method is about 2.5 C over the useful range of concentrations. The range bars on figure 1 show the range of values obtained when the same MPG solutions were tested by two different operators using three different examples of a density freeze point tester calibrated for MPG. It can be seen that the range is up to ±3 C indicating that the accuracy of measurement is within the difference of freeze temperature of the two glycol solutions. Furthermore, there are few places in Europe where protection to greater than -30 C is required so that normal glycol concentrations of 50% would provide adequate freeze protection for most circumstances.

For these reasons there is generally no need for the concentration of MPG based antifreeze solutions to be any greater than EG systems unless exceptional conditions are expected when higher concentrations may be used without difficulty.

4 CORROSION BEHAVIOUR

Corrosion protection of metals in an engine is very largely determined by the inhibitors used in the coolant mixture. However, the type of glycol does have

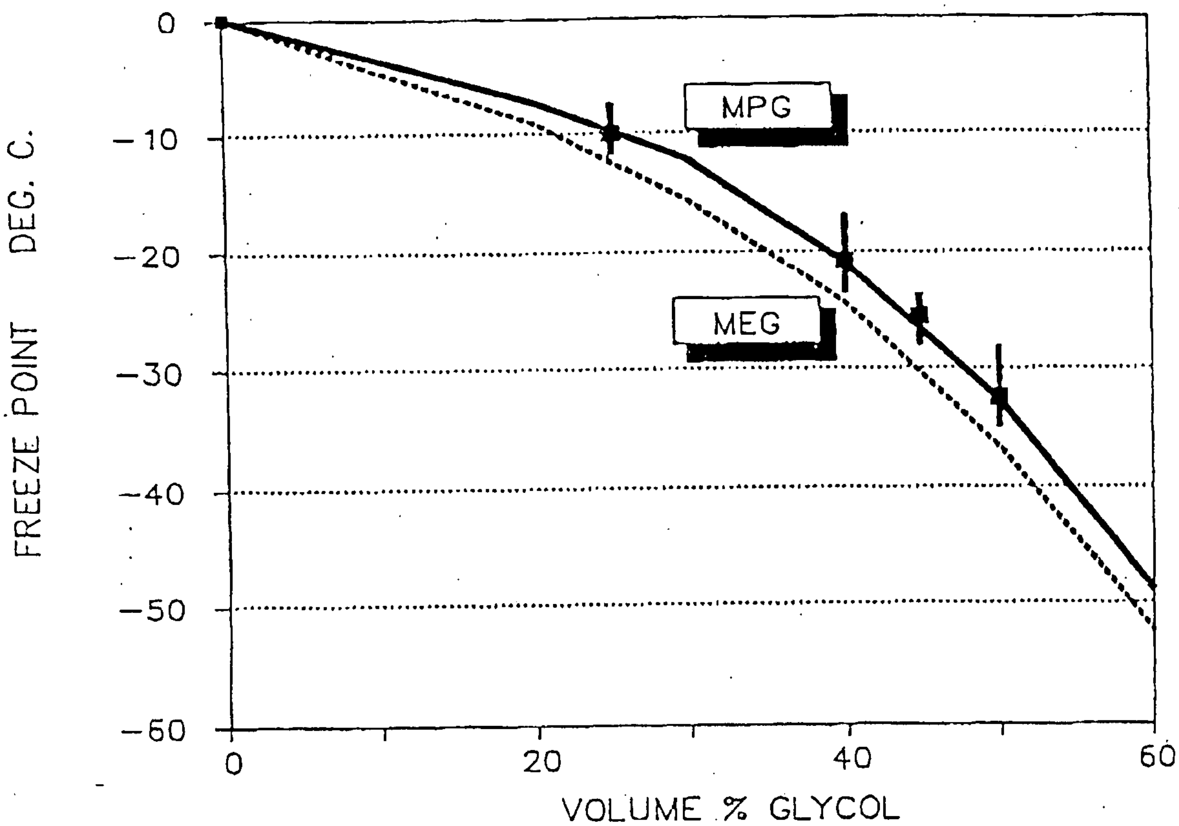

FIG. 1 – Showing ASTM D-1177 Freezepoint as a function of Glycol Concentration

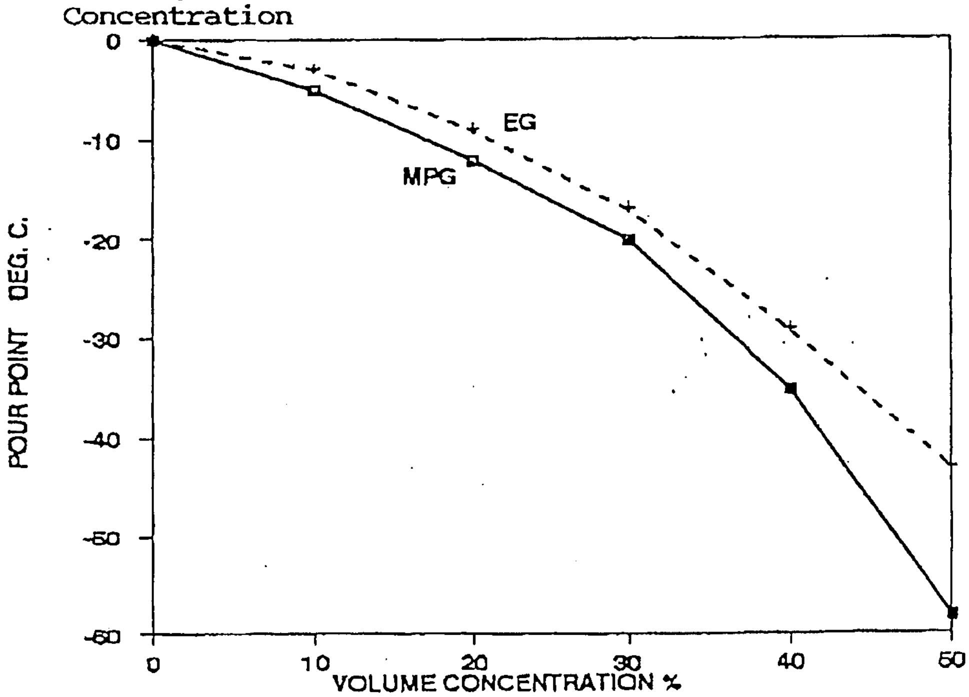

FIG. 2 POUR POINT OF MPG AND EG SOLUTIONS

a significant effect on the type of corrosion caused by cavitation of the coolant and which results in severe pitting of metal surfaces. This problem is particularly severe on the wet cylinder liners of heavy duty diesel engines and on the impellers of some water pumps.

In both laboratory and engine tests comparing the two types of glycol, MPG has been shown to give a significant improvement in protecton against cavitation corrosion of cast iron and aluminium. Hercamp, Hudgens and Coughenour[1] carried out laboratory tests using a cast iron probe vibrating at 20 kHz and 1.25 x 10^{-3} amplitude to generate cavitation conditions in 15% commercial coolant solutions. They compared the weight loss after 6 days at 71 C for EG and MPG based systems both with the same inhibitor package. Their results indicate a clear advantage for the MPG based system which resulted in a weight loss of only 6.3 mg compared with 23 mg for the EG coolant.

The results from these tests were confirmed in running a modern, high powered diesel engine on a dynamometer where the MPG coolant was shown to eliminate completely any pitting of the cylinder liners. They concluded that the use of MPG provides extra cavitation corrosion protection equivalent to at least 20 to 40% more than the inhibitors in a conventional formulation. Other points to emerge from these tests were:

a) engine temperature, fuel consumption and other performance parameters were similar for both systems,
b) MPG is more resistant to oxidative degradation than EG and the coolant may therefore last longer,
c) there is a reduction in the corrosion of aluminium when tested under heat rejection conditions (ASTM 4340).

5 SAFETY AND ENVIRONMENTAL ISSUES

There are increasing demands from consumers for safer and environmentally acceptable products to replace those which are either dangerous or pollute the atmosphere. This is particularly strong for chemicals which have a generally poor image in the consumers' mind. If safer alternatives exist, therefore, it must be right to use them. It is in this respect that MPG shows an important benefit over EG.

EG is classified by the FDA and the EEC authorities as harmful and as a result is subject to OSHA and COSHH regulations. In the EEC any antifreeze made with EG has to carry the St Andrew's cross indicating it to be a dangerous product. This is no scare story as there are recorded instances of human deaths

from drinking antifreeze. In the USA over 50% of all deaths from poisoning of cats and dogs are attributed to EG. The American Occupational Safety and Health Administration requires that exposure to EG does not exceed 50 ppm. This value was "Based on evidence of an occupational risk of severe throat and respiratory irritation". In the EEC the limit is 60 mg m^{-3} for vapour and 10 mg m^{-3} for a mist of suspended particles with a maximum of 125 mg m^{-3} over a ten minute period. In contrast, MPG is classified as "Generally Regarded as Safe" by the FDA and is widely used in petfoods, cosmetics and detergents as well as being an antidote for EG poisoning.

In recognition of this difference in toxicity, the Swiss Poison law of 1972 banned the sale of EG antifreeze in supermarkets, shops and generally across the counter to the public. Austria introduced a smilar law in 1989 after problems with poisoning from EG in wine. For this reason MPG antifreeze concentrates are widely used in these countries and have given no problems.

MPG is readily biodegradable and is classified as relatively harmless to freshwater and marine algae, invertebrates and fish according to a toxicity rating of the US Fish and Wildlife Service. It has no known detrimental affect on the environment.

ARCO Chemical Company is a leading world wide producer and supplier of propylene glycols with factories in Europe, Asia and the USA and sales organisations in all major markets. MPG is a world scale commodity chemical with current capacity approaching 1 million tonnes. Availability is therefore no problem.

MPG based coolants are available now and have gained wide acceptance in Italy as well as Switzerland and Austria. The growing awareness of the advantages it affords, from both a technical and safety point of view, will ensure it is used more extensively in future. After all:- *if there is a safer alternative available, why not use it?*

6 NON-AQUEOUS OR HYBRID™ COOLANT SYSTEMS

No discussion of MPG based engine coolants can be complete without some mention of a very interesting development where all water is eliminated from the system. Such a system has been developed over the last ten years by Jack Evans of MECA Developments Inc. and Tom Light of National Technologies Inc. in the USA. This subject merits a whole paper to itself as indeed the above gentlemen have presented to many distinguished audiences. However, this paper summarises the most important aspects of the system.To understand the

reasoning behind the idea it is necessary to review the mechanism of heat transfer from the engine to the cooling system and subsequent dispersion.

There are two principal mechanisms at work; convection and nucleate boiling. Convection is the mechanism operating in the radiator and to some extent in cooling the engine block in the cooler areas. The efficiency obviously depends upon the specific heat, conductivity and viscosity of the medium; water is very good in this respect.

When the temperature of the metal approaches the boiling point of the cooling fluid localised vaporisation occurs at the interface between the metal and the fluid followed by immediate condensation of the vapour in the bulk fluid. This vaporisation and condensation (referred to as nucleate boiling) transfers very high quantities of heat to the fluid since, of course, the heat of vaporisation of a liquid is much higher than the specific heat.

Problems arise with this method of heat transfer when the engine operating temperature is close to the boiling point of the coolant for a given pressure. Under these conditions the vapour cannot condense efficiently and vapour accumulates at critical areas of the interface causing a vapour blanket and catastrophic reduction in heat transfer. Other problems result from flash vaporisation in the water pump causing loss of fluid circulation. After boil is also likely after the engine is shut down and residual heat dissipates into stationary coolant. For these reasons water based systems have to run at relatively low temperatures or under pressure to increase the boiling point.

Jack Evans conceived the idea of replacing water with a fluid having a much higher boiling point than water but which also had good heat transfer characteristics and did not freeze under normally encountered conditions. After considering a number of alternatives he concluded that MPG showed the best overall properties for his purpose. Some properties of MPG and a 50/50 mixture of EG and water are shown below:

Property	MPG	50/50 EG/water
boiling point	187	107
freezing point	-57	-37
heat of vaporisation (kcals mole^{-1})	12.5	9.8

The much higher boiling point and lower freezing or pour point of MPG are evident advantages. The high boiling point achieves the objective of a large

difference in temperature between the coolant and vapour temperature resulting in rapid condensation of any vapour formed. This ensures liquid is always in contact with the metal surfaces and reduces the possibility of hot spots being formed.

Of more significance is the high heat of vaporisation per mole of MPG compared with the water mix. For a given quantity of heat absorbed by vaporisation, this means that there is less vapour formed which in tum means there is again less chance of vapour blanketing or cavitation. Other advantages of the HYBRID™ system include:

a) no cavitation in the coolant pump resulting in longer life and reduced maintenance,
b) the flow of the coolant can be reversed giving more efficient cooling at the cylinder head where it is needed most and increasing the temperature of the cylinders so promoting more efficient fuel combustion,
c) elimination of cavitation corrosion of cylinder liners,
d) the coolant is at atmospheric pressure reducing the stress on hoses and seals. This is a major contributor to reduced maintenance of the engine,
e) antifreeze and supplementary coolant additives do not have to be used,
f) there are no dissolved minerals such as calcium salts which form scale on water systems and reduced thermal conductivity,
g) coolant temperatures can be increased and the radiator size reduced resulting from the more efficient heat transfer at the higher temperatures.

HYBRID™ coolant system has been extensively tested in laboratory and field trials. The main advantages that have emerged from these trials are considerably greater reliability of the engine as a result of the reduced coolant pressure and lack of corrosive material in the system. In racing engines running at maximum output for several hours there is a greatly reduced incidence of cylinder head cracking and corrosion from hot spots.

The patented system is still being developed by MECA Industries and National Technologies who are now marketing an inexpensive kit for trucks and high performance cars so that they can achieve maximum benefit from the system. Further information is available from Mr J. Evans, (MECA Developments Inc., Route 41 RR140, Sharon CT, USA 06069) or Mr T. Light (National Technologies, P.O. Box 1479, Sharon CT, USA 06069).

7 CONCLUSIONS

MPG has been shown to be an acceptable alternative to EG for use as a freeze

point depressant in automotive coolants. It has distinct safety advantages over EG and technical advantages especially when used in heavy duty engines.

The complete elimination of water in engine coolants by using 100% MPG has already proved beneficial in high powered racing engines. With the drive towards longer lasting sealed coolant systems, this may well be the preferred method for all cars of the future.

8 ACKNOWLEDGEMENTS

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REFERENCES

1. Hercamp, Hudgens and Coughenour, 'Aqueous Propylene Glycol Coolant for Heavy Duty Engines', Proc. Int. Congress, Detroit, 1990, SAE Techical Paper SP 811-900434.